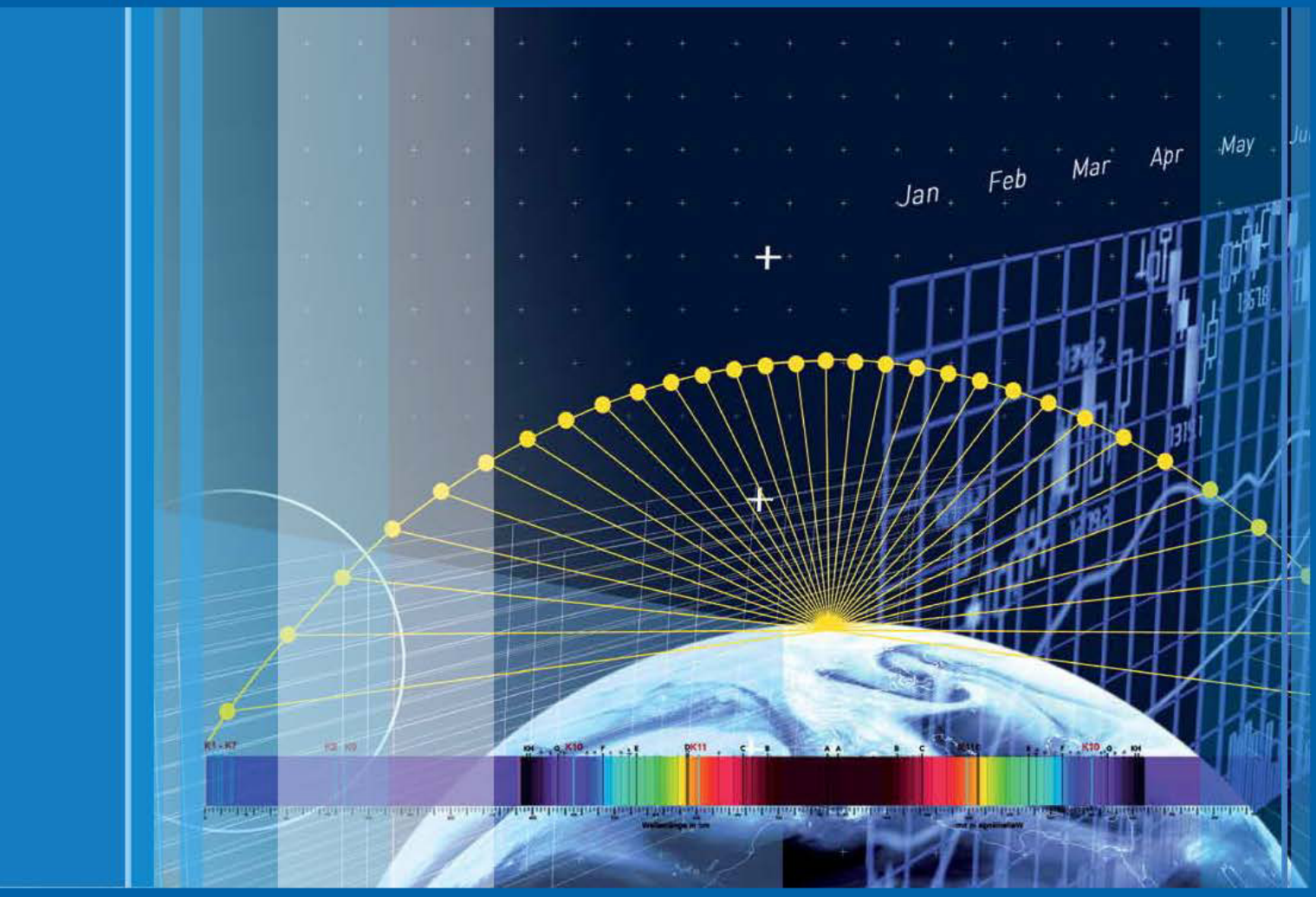
meteonorm

Global Meteorological Database

Version 7

Software and Data for Engineers, Planners and Education

The Meteorological Reference for Solar Energy Applications, Building Design, Heating & Cooling Systems, Education Renewable Energy System Design, Agriculture and Forestry, Environmental Research



Handbook Part I: Software

Version 7.0.0 / May 2012

meteonorm

Imprint

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Liability	The information contained in this handbook is provided without warranty and is subject to alteration without notice. The program developers cannot accept any liability. The computer program described in this handbook is licensed for use on one location computer only under the condition that it shall not be further distributed. No liability on the part of the developers shall arise from this. The user shall be responsible for checking the correctness and plausibility of the results by applying state-of-the-art control procedures.

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PART II: THEORY

See the theory manual!

1 Short Review

What is *meteonorm*?

meteonorm is a comprehensive climatological database for solar energy applications:

- ***meteonorm*** is a meteorological **database** containing comprehensive climatological data for solar engineering applications at every location on the globe. The results are stochastically generated typical years from interpolated long term monthly means. They represent a mean year of the selected climatological time period based on the user's settings. As such the results do not represent a real historic year but a hypothetical year which statistically represents a typical year at the selected location.
- ***meteonorm*** is a **computer program** for climatological calculations.
- ***meteonorm*** is a **data source for engineering design programs** in the passive, active and photovoltaic application of solar energy with comprehensive data interfaces.
- ***meteonorm*** is a **standardization tool** permitting developers and users of engineering design programs access to a comprehensive, uniform meteorological data basis.
- ***meteonorm*** is **a meteorological reference** for environmental research, agriculture, forestry and anyone else interested in meteorology and solar energy.

What is it based on?

meteonorm's orderly facade conceals not only numerous **databases** from all parts of the world but also a large number of computational models developed in international research programs.

***meteonorm* is primarily a method for the calculation of solar radiation on arbitrarily orientated surfaces at any desired location**. The method is based on databases and algorithms coupled according to a predetermined scheme. It commences with the user specifying a particular location for which meteorological data are required, and terminates with the delivery of data of the desired structure and in the required format.

Depending on user requirements, the calculation procedure employs between one and four computation models (Tab. 1.1). In addition to the monthly values, ***meteonorm*** provides maximum radiation values under clear sky conditions. For Switzerland, standardized data (design reference years) for building simulation purposes are available for a number of locations.

Tab. 1.1: Sequence in which the computational models are coupled in generating hourly radiation data on an arbitrarily orientated surface at a site for which no measurements are available.

Computational step	Description
Interpolation with monthly average value model G_h, Ta	Space dependent interpolation of horizontal radiation and temperature based on weather data taking altitude, topography, region etc. into account
Hourly value generator G_h, Ta	Stochastic generation of time dependent global horizontal radiation and temperature data having a quasi-natural distribution and an average monthly value equal to the average value over 10 years
Radiation resolution $G_h \rightarrow D_h$, B_n	Resolution of global radiation into diffuse and direct components
Radiation on inclined surface with skyline effect, hourly value model G_k	Calculation of hemispherical radiation on arbitrarily orientated surfaces taking the reduction due to skyline profile into account

Which data for what purpose?

Depending on his specific requirements, the user must choose the most suitable method from among the numerous procedures available in ***meteonorm***. To provide the user with the best possible service, a whole series of dependent parameters in addition to the measured data are available. In choosing the data, the quality and relevance of the basis data sets must be considered. The following criteria should be applied:

- **Measured and interpolated monthly values** are of similar precision. Although measured data reflect the specific characteristics of a local site, they are always subject to measurement errors, and these tend to be compensated by the interpolation process. Interpolated data should therefore be used at sites with no weather station in the vicinity (approx. 20 km distance).
- **Dependent parameters** such as diffuse radiation, celestial radiation, dew point temperature etc., which are determined from calculated as opposed to measured data, are subject to greater inaccuracy owing to error propagation.
- **Design reference year** – DRY – data (for Switzerland and USA) should preferably be used in situations for which they were generated and tested, i.e. for building simulations. This is because, like generated data, they are produced from original data via a data transformation procedure.

What has changed since the last edition?

Compared to version 6.1, version 7 is completely redesigned and modernized. Version 7.0 includes **more data** and many **additional features**:

- Database:
  - Update of the time periods for temperature, humidity, precipitation and wind speed: periods 1961–1990 and 2000–2009; for radiation parameters 1981–1990 and 1986–2005.
  - Update of the satellite database. Inclusion of completely new high resolution satellite map for Europe (produced by MeteoSwiss).
  - Access to climate change forecasts (IPCC scenarios B1, A1B, A2).
  - Wind load zones for Germany and Switzerland.
  - Snow load zones for Germany, Switzerland, Austria and France.

- Models:
  - Enhanced interpolation models to calculate mean values for any site in the world
  - Additional models for calculation of diffuse and direct radiation.
  - Enhanced temperature and humidity generation for building simulation (including extreme events).
  - Uncertainty, variability and trend information of yearly values of radiation and temperature for any site.
- Software:
  - Total redesign of software and graphical user interface: e.g. new high resolution map tool, easier activation of the software with a license key.
  - Update of the data import interface for user defined data (including current data by internet).
  - Effects of high horizon considered in radiation calculations. High horizon calculated automatically for all regions worldwide.
  - Calculation of panel reflections.
  - Update of the English user manual, maps and illustrations included.
  - New output formats added: IBK-CCM, Solinvest.

How accurate is *meteonorm*?

Owing to the comprehensive framework chosen for the present edition, certain inconsistencies could not be avoided. However, it is always possible to establish which data basis and algorithms were used. Differences between the various data bases and algorithms may be summarized as follows:

- **Quality of the data basis:**
  The radiation and temperature data was subjected to extensive tests. The root mean square error in interpolating monthly radiation values was found to be 7%, and for temperature 1.2°C.

- **Climatic variations:**
  The ***meteonorm*** radiation data base is based on 20 year measurement periods, the other meteorological parameters mainly on 1961–1990 and 2000–2009 means. Comparisons with longer term measurements show that the discrepancy in average total radiation due to choice of time period is less than 2–3% (rmse) for all weather stations.

- **Computational models:**
  The models used in ***meteonorm*** are designed to calculate radiation on inclined surfaces and additional meteorological parameters. One or more models are used depending on data basis. If the results are to be passed on to another software, the data basis and models used should be specified to ensure that the results are correctly interpreted.

- In general, the **hourly model** tends to slightly overestimate the total radiation on inclined surfaces by 0–3% (depending on the model). The discrepancy compared to measured values is ±10% for individual months and ±6% for yearly sums.

It is important for users of ***meteonorm*** to be aware that the data basis and computational models only approximate the real situation. Notwithstanding this, the mean variation in measured total radiation between one year and another is greater than the inaccuracy in the models.

2 Software Description

2.1 Delivery, license agreement

The ***meteonorm*** software can be downloaded at http://meteonorm.com/download/software/. The purchaser is entitled to use the software and data supplied for his own purposes. The licensing conditions to be adhered to are published on http://meteonorm.com/products/software/license/. They are displayed when ***meteonorm*** is installed and are available in the software in the menu *Help → About meteonorm 7*.

2.2 Installation

The installation package for the software can be downloaded from the internet at www.meteonorm.com/download/software. The file downloaded is an easy-to-use installation package. Run the downloaded file and follow the instructions given.

To install and run the program, a personal computer with Windows XP/Vista/7 is required. 800 MB of storage space is required on the hard disk. At least 512 MB RAM is needed. If not present, the .NET framework 4.0 (freely available from microsoft.com) will be installed automatically. A screen resolution of at least 1024x800 pixels is recommended. An internet connection is required for license checking.

The license conditions must be read prior to installation. See chapter 2.1 where to find them.

The program is by default installed to the "mn7" directory:

C:\Program Files\Meteotest\meteonorm 7.

If required, the directory can be changed. Additionally software specific as well as personal configuration files are stored in the user's configuration directory, e.g.:

c:\Users\<username>\AppData\Roaming\Meteotest\meteonorm7

The meteonorm7.exe file and several files are contained in the mn7 directory. The program is started with the meteonorm7.exe file or with an entry in the start list provided by the installation program.

The operating language of the program is English (default), but this can be changed during program operation (see 2.2.3). Help is only available in English.

After installation the software runs in demo mode which has restrictions in saving data files. For full usage of the software a license key is required.

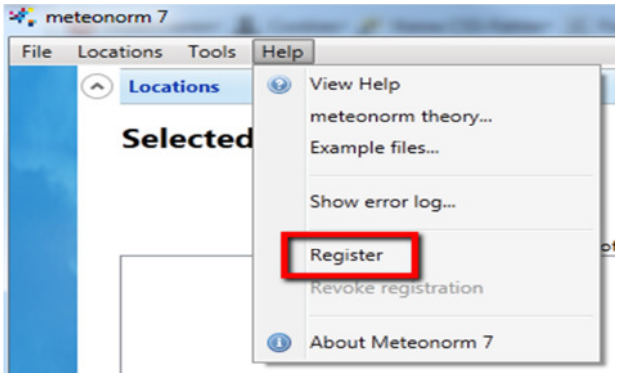
See also online installation instructions: http://meteonorm.com/register/guide/.

2.2.1 Software activation

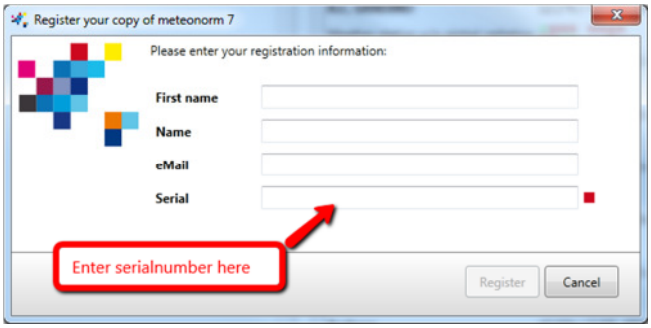
With your license key which you receive after buying a license you can activate the full functionality of the software. The license runs only on 1 computer at the same time. The license cannot be activated a second time when it is already activated. First revoke the license registration in order to register it on another computer.

2.2.1.1 Activate your license

1. In the *Help* item in the menu bar select the entry *Register*. An internet connection is needed.



2. Enter your license key (16 character long string) to register and obtain full software usage. Enter your personal information for a quicker identification in case you have support questions and click ok.

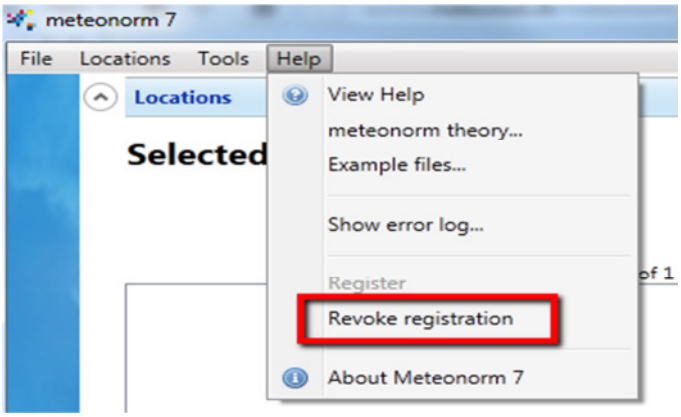


3. You will be informed by a popup window on the success of the activation process. Push the Start button for working with ***meteonorm***.

In case the license is already activated on another machine, the license has to be revoked there first.

2.2.1.2 Revoke your registration

1. In the *Help* item in the menu bar select the entry *Revoke registration*. An internet connection is needed.



Your license will be deactivated and ***meteonorm*** will restart in demo mode.

2.2.2 License transfer

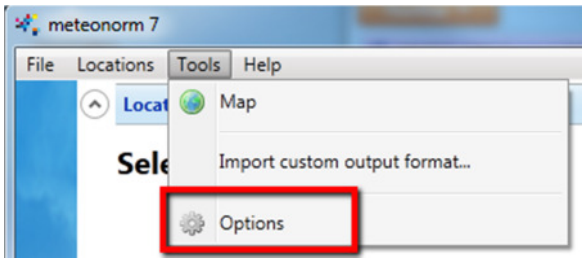
To transfer a license to another computer:

1. Revoke your license registration on the old computer.
2. Install ***meteonorm*** on the new computer and activate your license there.

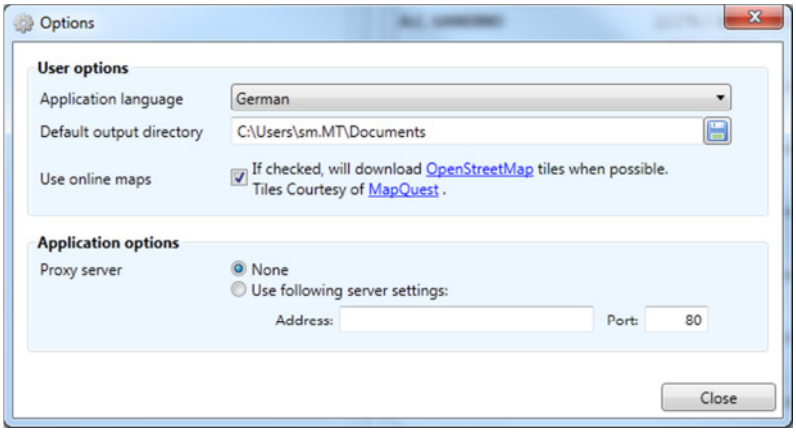
In case your license cannot be revoked due to a computer crash, contact support@meteonorm.com to deactivate your license manually.

2.2.3 Basic settings

Use the *Tools* menu item *options* to set your specific options.



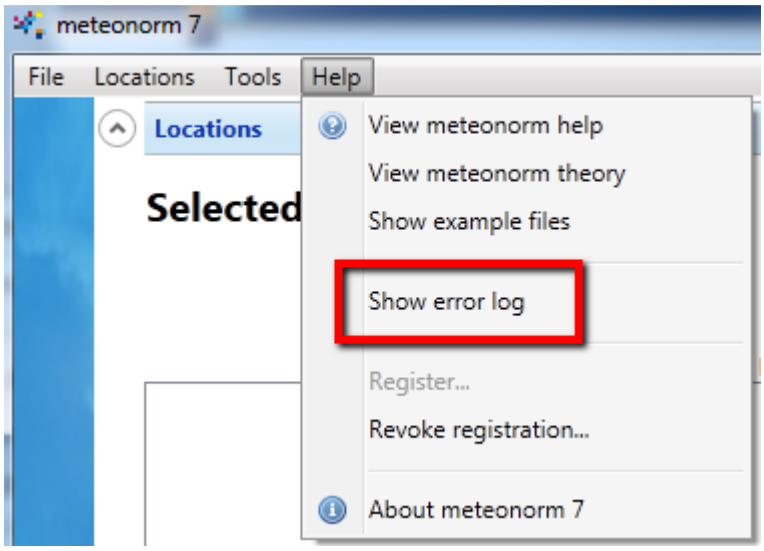
A popup window opens for the settings:



- User options:
  - **Application language**: Language settings of the software.
  - **Default output directory**: Directory where per default the results are written to.
  - **Use online maps**: Select to use higher resolved MapQuest tiles from the internet whenever possible.
- Application options:
  - **Proxy server**: Set your proxy server settings if a proxy server is used in your local area network.

2.2.4 Error Log

In case of software crashes errors are written to an error log file. You can access this file over the menu *Help → Show error log*.



A text editor opens showing the errors.

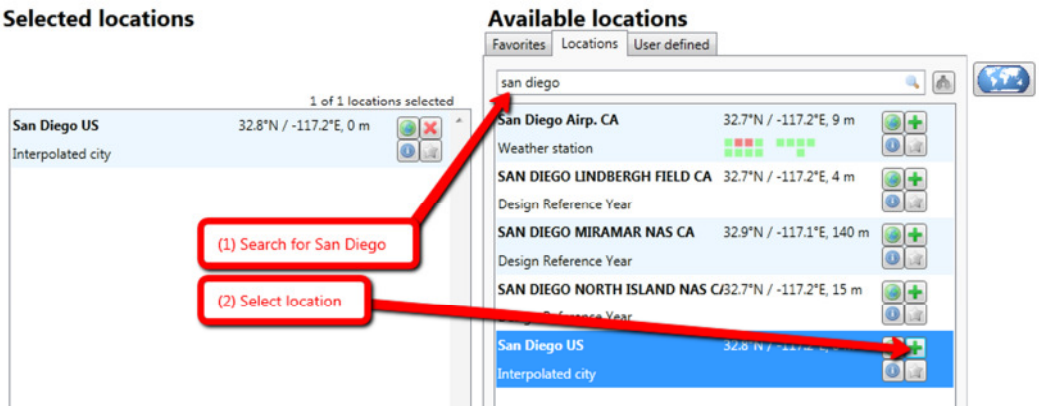
2.3 Software usage

meteonorm supplies meteorological data at any desired location in the world as monthly, daily, hourly or minute values in various output formats. The example in chapter 2.3.1 provides a quick initial introduction to the main features of the program for a basic usage of the software. In chapter 2.3.2 a more detailed description of the software features is given.

2.3.1 An introductory example

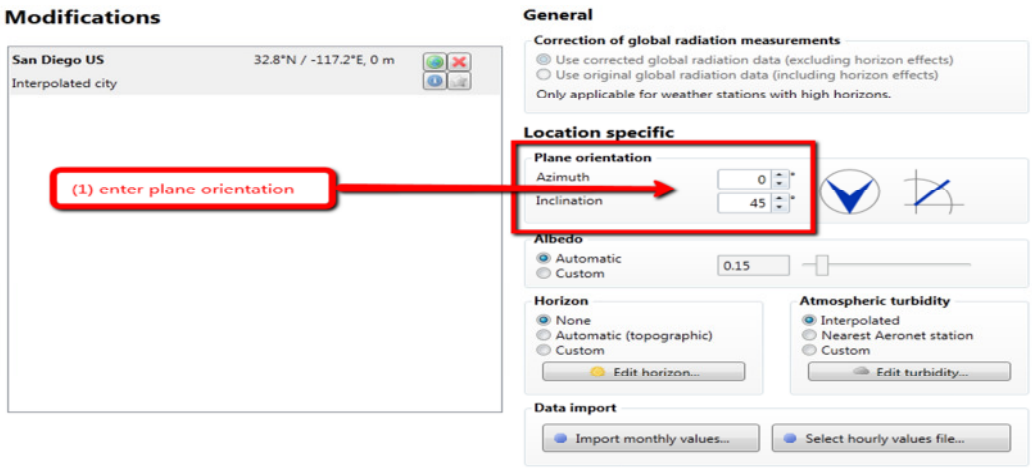
Example: For a design project in San Diego (CA, USA), hourly values of global radiation on a south-facing surface inclined at 45° and of the temperature are required. The user has no data of his own. Proceed according to the steps shown below:

1. **Locations form:** Select San Diego from the "Available locations" list in the "Locations" tab on the right side of the application window. You can search the list by typing "San Diego" in the search bar above the station list. Add the location to the list of selected locations on the left side of the window by clicking on the green plus sign on the right of the station name or by double-clicking the entry.



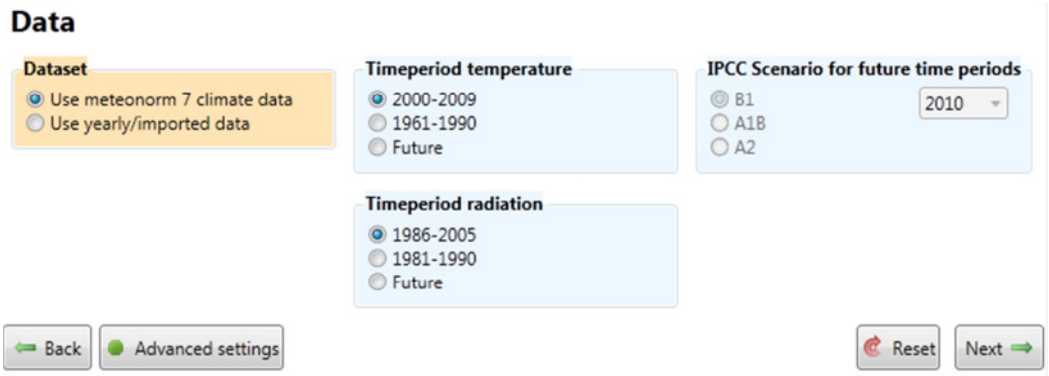
Press the *Next* button on the bottom right to move to the next page.

2. **Modifications form:** Enter the plane orientation by typing 45° in the inclination box, and leave the azimuth at 0° (due south) to set the right orientation.



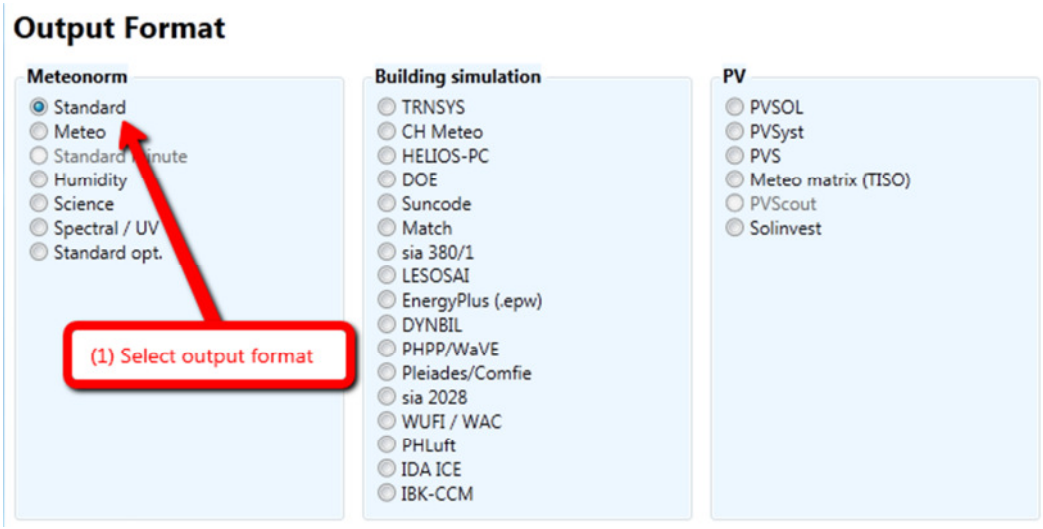
Press *Next* on the bottom right to move to the next page.

3. **Data form:** Leave it as is to use the default selections.



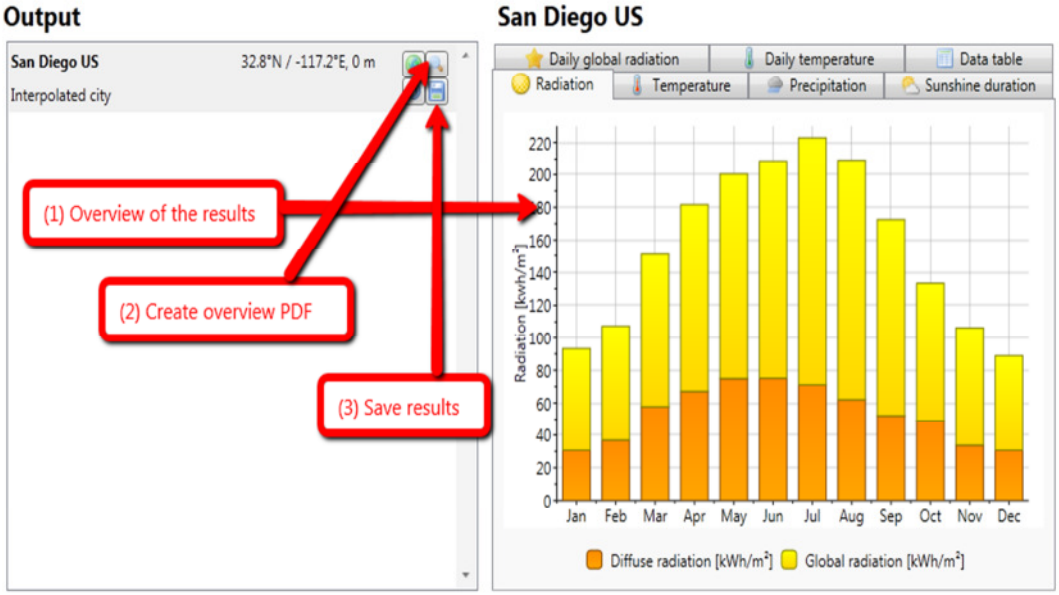
Press *Next* to move to the next page.

4. **Output Format form:** Choose output format *Standard*. The ***meteonorm*** standard output file contains the global radiation, diffuse radiation, global radiation inclined, diffuse radiation inclined, direct normal radiation and air temperature.



Press *Next* to run the calculations.

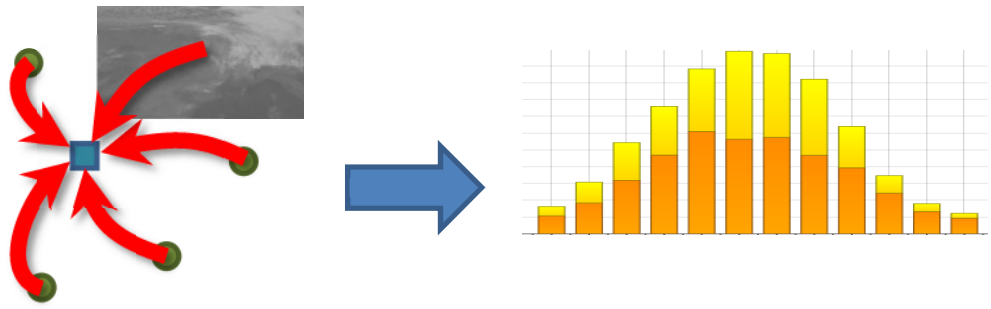
5. **Output:** The calculation takes about 2 to 10 seconds. The monthly values are first interpolated, then the hourly global horizontal radiation values and the temperature are calculated, and finally the radiation on the inclined surface is calculated. The results are shown in the display. The monthly average values of the resulting parameters can be displayed with the *View results from all locations* button and saved as a PDF document.



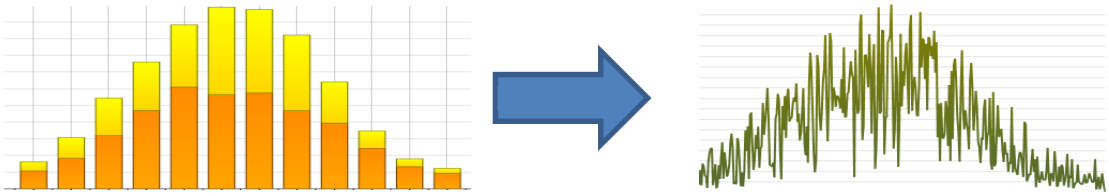
6. By pressing the *Save all results on disk* button you can store the values. In the opening dialog box select the time format of the data *Month* for monthly values, *Day* for daily values or *Hour* for Hourly values.

2.3.2 Detailed software overview

The software basically works in two steps. In a first step, surrounding weather stations are searched and their long-term monthly means are interpolated to the specified location. Data derived from satellite imagery help to improve radiation parameters in regions with a low density of available ground-based data.

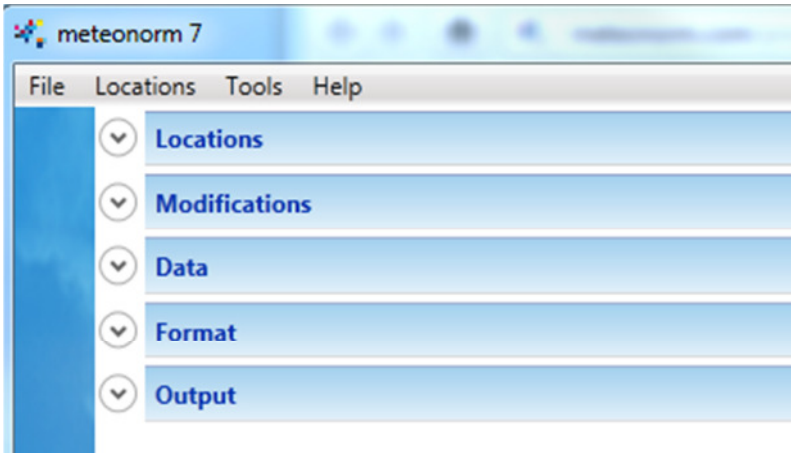


In a second step, a stochastic weather generator runs on the interpolated monthly data to generate a typical mean year of data in hourly resolution (8'760 values per parameter) for most of the output formats. Some of the output formats even require a minute-by-minute time resolution.



2.3.2.1 Introduction

To obtain a result, a user has to consecutively go through the following five steps:



1. Locations: Select the locations for which you want to run ***meteonorm***.
2. Modifications: Modify the location specific settings.
3. Data: Adjust data settings.
4. Format: Set the output format.
5. Output: Calculate and store the results.

2.3.2.2 Step 1: Locations

It is important to choose the location that suits your needs best. Based on the selection of a location the data basis can be different since the **sites and the databases are intimately coupled**.

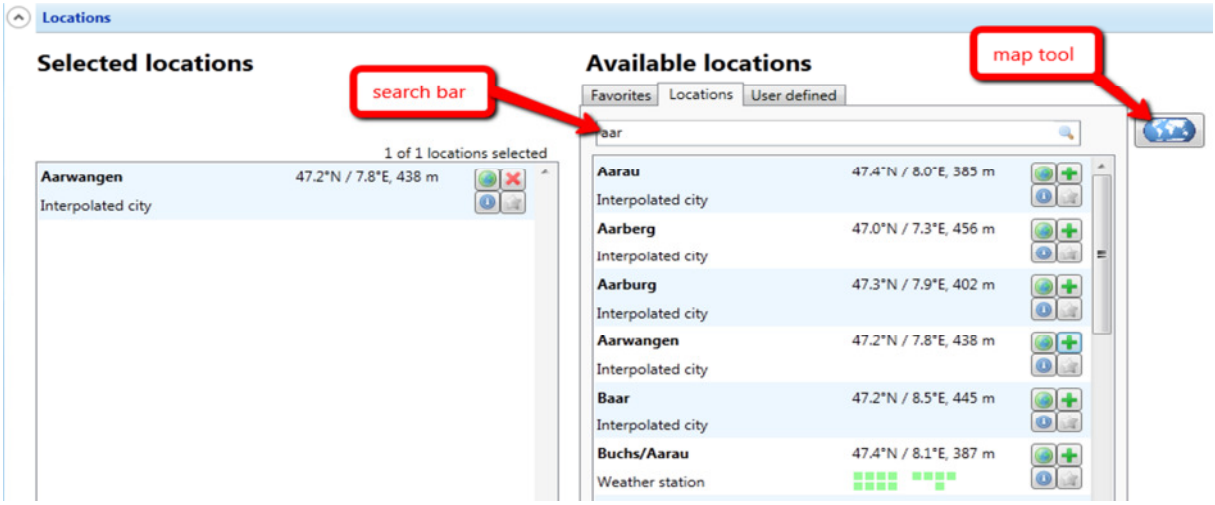
Basically, there are seven different site types for locations defined: Interpolated cities, weather stations, weather stations without global radiation measurement (that means global radiation is interpolated for them), design reference years (DRYs), user-defined sites, sites with imported monthly values (*User (month)*) and sites with imported hourly values (*User (hour)*). Worldwide, cities with more than 100'000 habitants – and for Switzerland all 3'020 municipalities – are included.

To have ***meteonorm*** calculate meteorological data, the question of which data basis to use arises. Do you have your own data, should one of ***meteonorm's*** built-in sites be used, or should an interpolation based on the nearest ***meteonorm*** sites be used?

The fixed database in ***meteonorm 7*** contains approx. 6'200 cities, 8'300 weather stations and 1'200 DRY (Design Reference Year) sites. For weather stations, monthly average values are stored. Should you require hourly values, these are generated accordingly. For cities, the monthly average values (long term averages) are interpolated and then the hourly values generated. For other sites, the monthly values are likewise interpolated and hourly values generated. If you choose a DRY site, the stored hourly data will automatically be read in and used in the calculations.

If your project is near a weather station, this station can be used directly. The distance between your location and the nearest weather station should not be more than 20 km, and the altitudes should not differ by more than 100 m. When a weather station is selected, its data is used in the calculations.

If your project lies far from the next city or weather station included in ***meteonorm***, it is recommended to define a user defined site (form *Available Locations* – Tab *User defined* – button *Add new...*) so that data from nearby weather stations are interpolated.

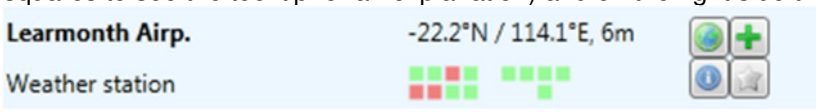


The Location selection window is divided into two parts. To the left you can see the list of your selected locations and to the right the list of selectable locations, divided into three tabs.

- The *Favorites tab* is a list of the locations you marked as your personal favorites. This is shown per default on starting up if it is not empty.

- The *Locations tab* lists all the pre-defined locations. Weather stations as well as interpolated cities and Design Reference Years are mixed. You can search over the search bar for certain location names. With the filter button, you can filter the list by station types and continent.

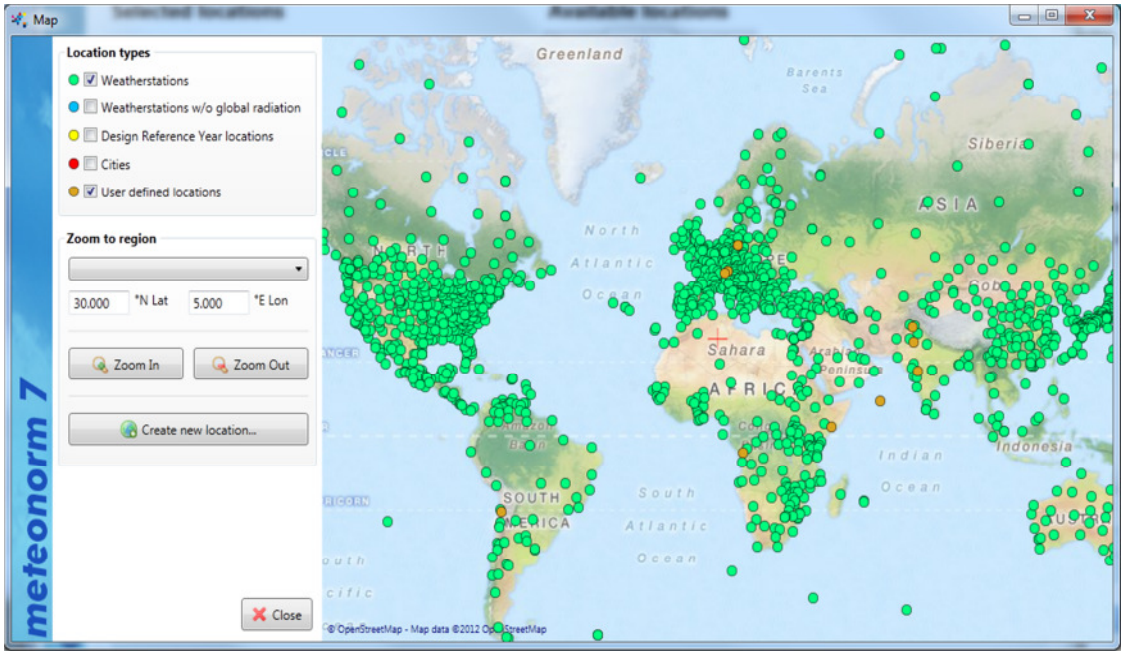
  For each location, a short description of the location is displayed: The name and the site type on the left side, the coordinates and weather parameters available for either the old and the newer period as green and red squares in the center (move your mouse over the colored squares to see the tool tip for an explanation) and on the right side the selection toolbox.

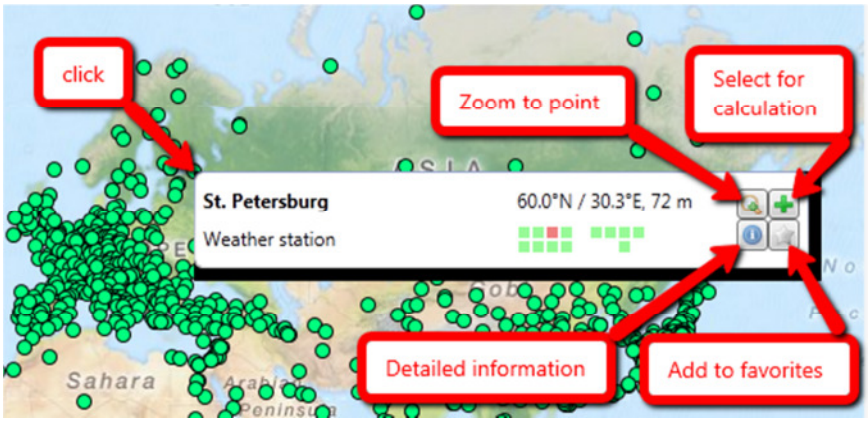
- The *User defined tab* lists your own added stations. You can add new locations by clicking the *Add new...* button. Details for defining a new site are given in the section "Defining a user defined site" below.

The selection toolbox contains four buttons. The globe sign on top left opens the map tool and a map centered to the coordinates of the location is displayed. With the green plus sign on the top right you can select the location for your calculations. The location will be added to the list of selected locations on the left side of the window where the green plus sign is turned into a red cross for removing the station out of the selected location list. You can also select and deselect locations by double clicking. When pressing the information button on the bottom left a window with location specific information will pop up. The greyed star on the bottom right adds the location to your favorites. The color of the star will change to yellow when the location is included in your favorite list.

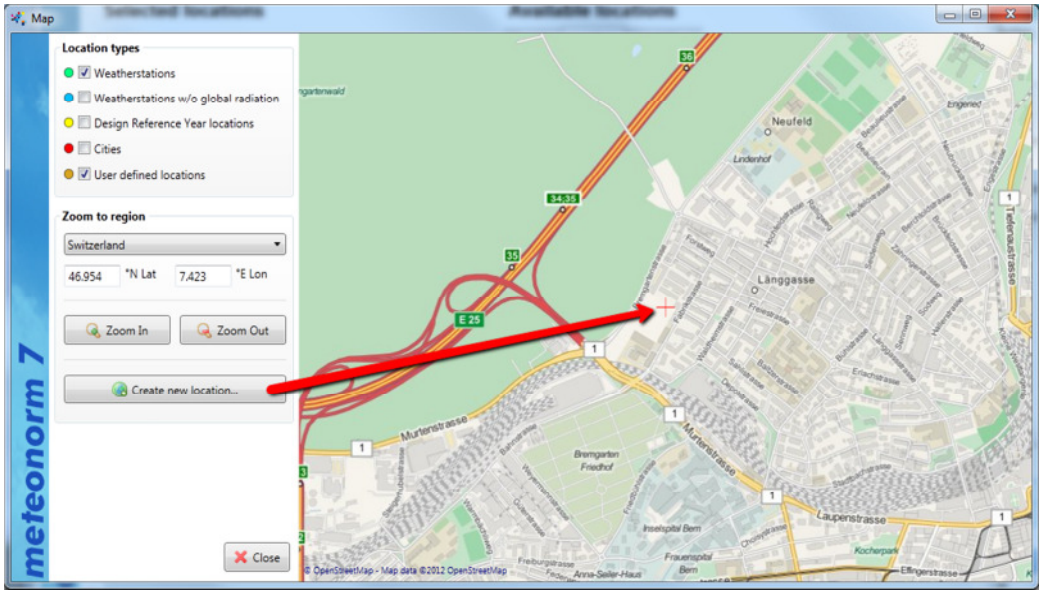
In addition to the lists, all sites may also be chosen on a World *Map*. This is accessed with the *Map* icon on top right of the Locations window. To zoom in and out you can either use the buttons at the bottom of the window or using the mouse wheel. Pan the map by clicking and dragging. Locations are marked as colored dots on the map. They can be switched on and off with the check boxes on the left side under location types.



More information about a location is displayed when clicking on a location dot in the map. You will see the same type of location bar as in the list of available locations. You can then directly select a location for your calculation or view details with the available buttons.

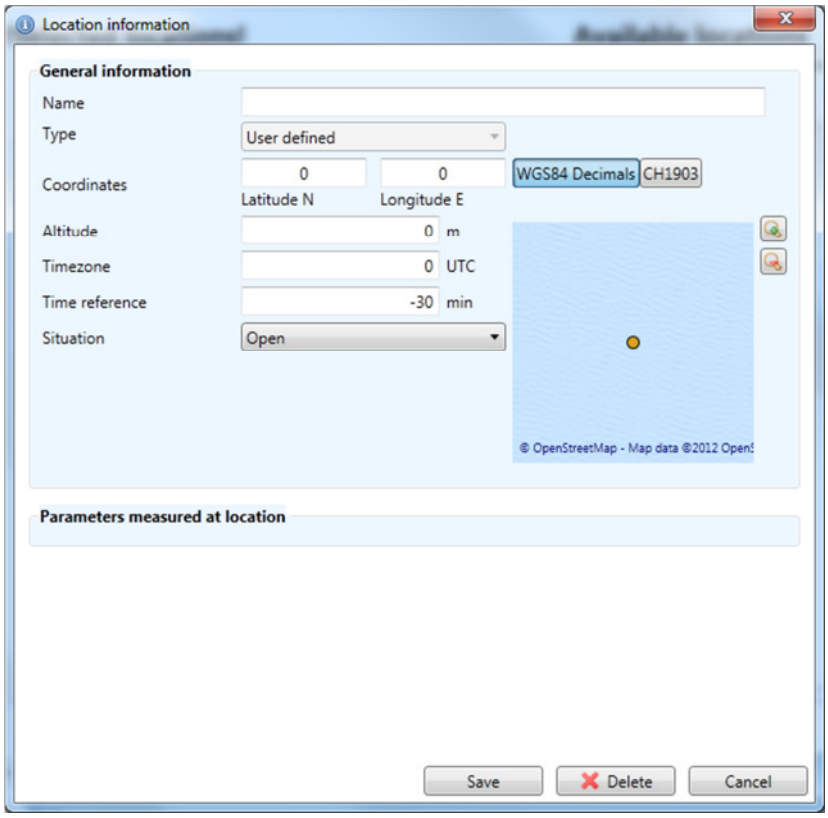


In the center of the map you can see a red cross. To define a new *User defined* location click on the Create new location button. The coordinates for the new location will be taken from the position of the red cross. In the window opening enter a name for the location, the altitude and time zone. See the subsection "Defining a User defined site" below for further instructions.



Defining a *user defined* site

If your project site is not in the vicinity of a predefined city or weather station, it is recommended to specify a user defined site.



To specify a user defined site, the following parameters must be available:

- name of site
- coordinates (as longitude, latitude in decimal degrees)
- altitude

If altitude is left empty, ***meteonorm*** will retrieve the information from its digital terrain model. Specification of time zone, terrain (situation) and time reference are optional. Default values are used if omitted. The default value for the time zone is that of the corresponding country (defined in a 1° grid). For Central European Time (CET), it is +1. The sign of the time zone matches the general standards. Daylight saving time is ignored.

The time reference in minutes specifies the difference between the center of the interval and the full hour. The default value is -30. This means that the current full hour designates the end of the interval. For example, 14:00 hours designates the time interval 13:00–14:00 hours. The time reference is explained in detail in the ***meteonorm*** Theory Manual in chapter 6.

The default value for the location situation (i.e. the surrounding terrain) is *open situation*. In the section *Situation*, this can be changed. The specification of the situation is central to the interpolation and generation procedure, and must be very carefully considered. There are 14 types of situations from which to choose (Tab. 2.3.1). They are classified according to the local surroundings as shown in Figure 2.3.1 and Tab. 2.3.1.

Tab. 2.3.1: Definition of location situations.

Terrain	**Features**
Open	Open site, open terrain, north facing incline, no raised skyline. Applies to most sites.
Depression	Depression or very flat valley floor, in which cold air collects, (e.g. in Switzerland particularly in the Jura and the Alps).
Cold hollow	Extensively cold hollows.
Sea/lake	Shore of sea or larger lake (up to 1 km from the shore).
City	Centre of larger city (over 100'000 inhabitants).
S incline	South facing incline (above approx. 10° inclination, facing between SE–S–SW). At least 200 m above valley floor.
W/E incline	West or east facing incline (exceeding approx. 10° inclination, facing between SW–W–NW or NE–E–SE). At least 200 m above valley floor.
Valley	Valley floor in mountainous valley at higher altitudes. Valley floor inclined (flat valleys are often treated as depressions).
Valley Central Alps	Floor of large central Alpine valley (e.g. Alpine regions of Valais, Switzerland).
Föhn valley	Valley floor of Föhn valley (regions with warm descending air currents).
Valley Alpine foothills	Valley floor in northern Alpine foothills.
S valley side	South facing incline (exceeding approx. 10° inclination, facing between SE–S–SW) up to 200 m above valley.
W/E valley side	West or east facing incline (exceeding approx. 10° inclination, facing between SW–W–NW or NE–E–SE) up to 200 m above valley floor.
Summit	Open summit above 500 m. Overlooking surroundings in all directions.

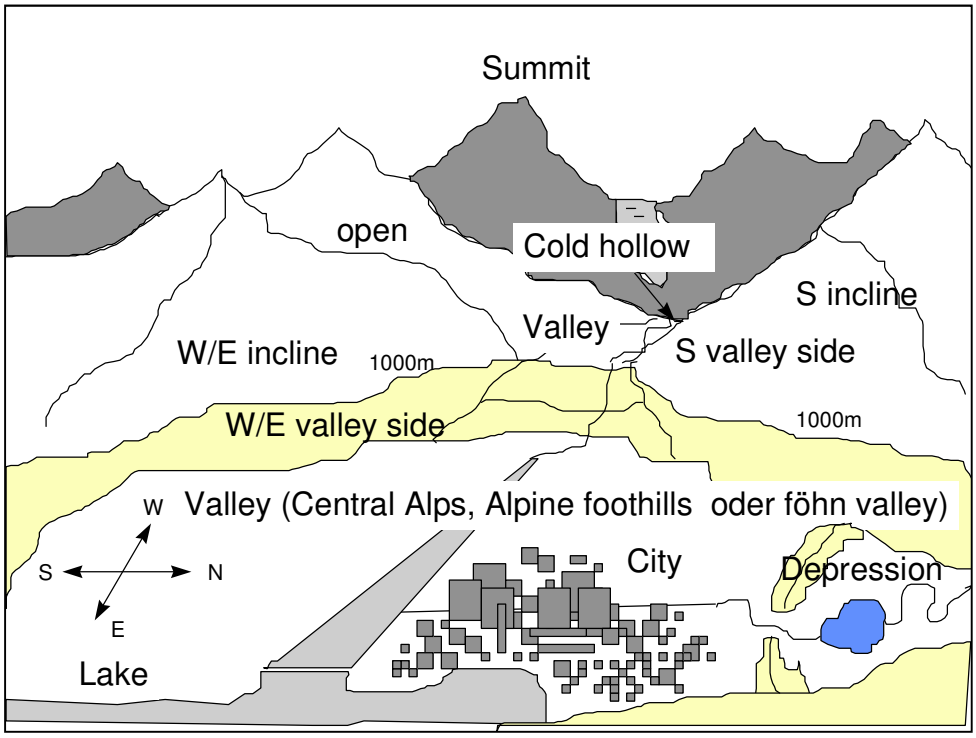
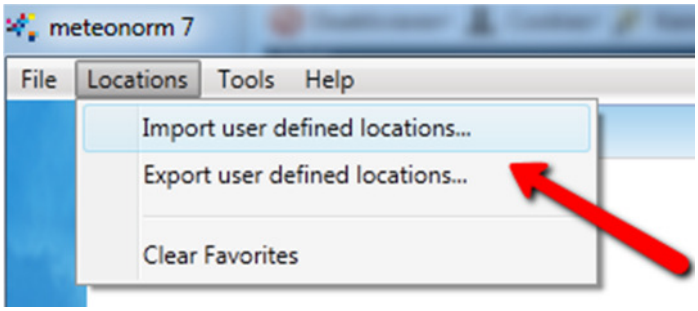


Fig. 2.3.1: Classification of the 14 types of terrain situations.

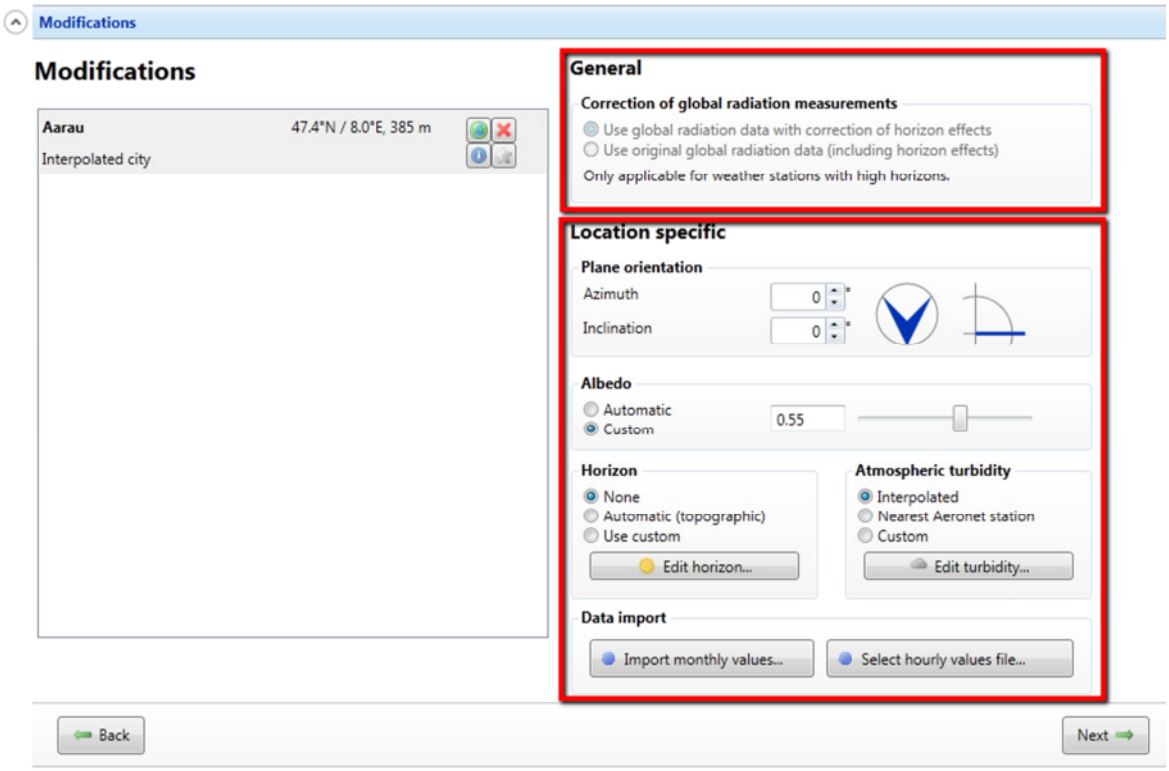
Exporting and importing the list of user defined locations

The list of your own user defined locations can be exported and imported. To do so go to Locations in the menu bar on top and select the appropriate function.



2.3.2.3 Step 2: Modifications

This part describes the site specific settings for a selected location.



General

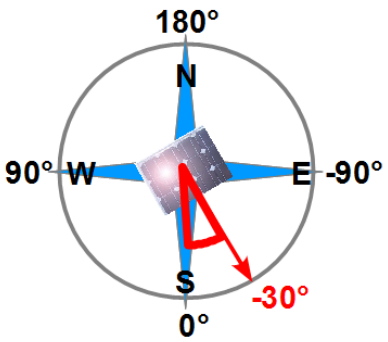
Corrections of global radiation measurements

This point affects only a few stations in deep valleys in the Swiss Alps where measurements are highly influenced by high horizons. The data is corrected as if there is no horizon line. This setting is only available if one of these stations is selected.

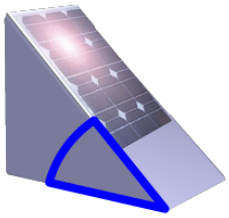
Location specific

Plane orientation

Here you can set the orientation and inclination of your solar panel for the calculations of the radiation components on the inclined plane.



Azimuth angle



Inclination angle

- The azimuth is the angle between the horizontal projection of the normal to the surface and due south. The azimuth angle is defined as follows: 0° = South / 90° = West / -90° = East / 180° = North.

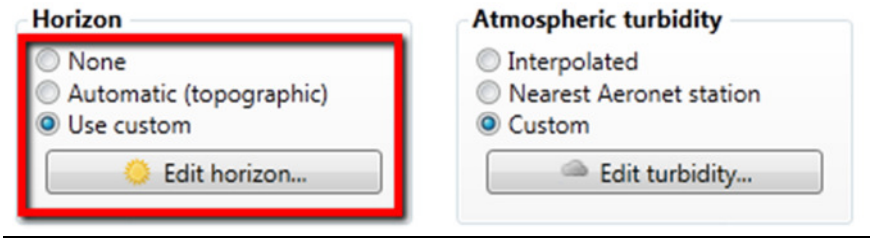
- The inclination angle is the angle between the surface and the horizontal plane, and ranges from 0° to 90° (0° = horizontal, 90° = vertical).

Albedo

The albedo can be set to a user defined value (*Custom*). The albedo is the part of the shortwave radiation that is reflected by the ground. It normally lies between 0.1 and 0.8 (mean values of grass are 0.15–0.2). Use the slider or enter the value directly in the input field.

If the albedo is not set by the user (selection *Automatic*), it is calculated using a temperature dependent model (see ***meteonorm*** Theory Manual 6.7.2). This model takes the snow coverage into account. This will cause the albedo value to be variable between winter (if there is snow) and summer.

Horizon



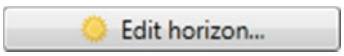
In ***meteonorm*** the influence of the horizon profile on the monthly and hourly values is taken into account. Should the horizon (for the Northern Hemisphere) be raised above 10° in the directions NE through S to NW, a noticeable reduction in average monthly radiation occurs. For hourly values, a relatively little elevated horizon may already have a strong influence on individual values. For these reasons it is important to consider the effects of a raised horizon.

The selection can be made whether to use:

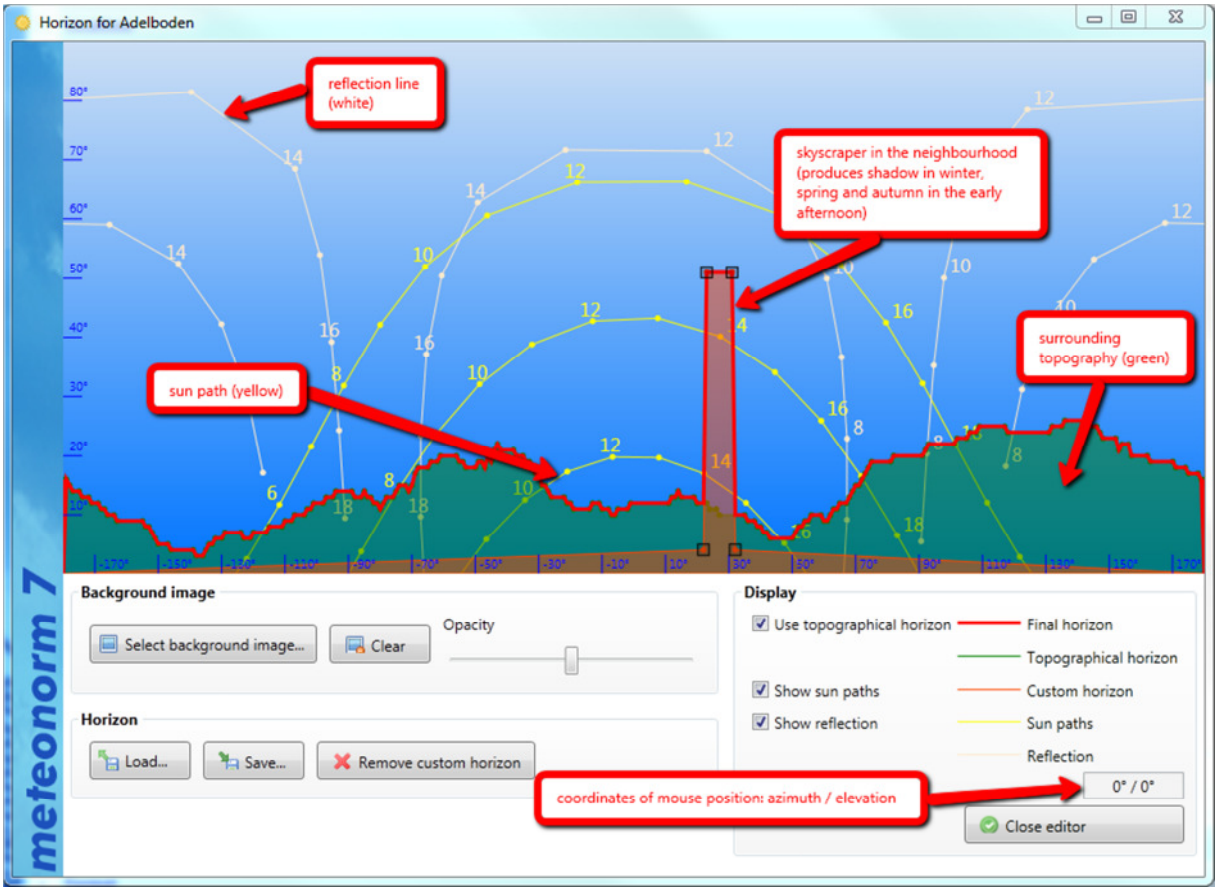
- **None**: Do not use a horizon line at all. The terrain is assumed to be flat and no shading is taken into consideration.

- **Automatic (topographic)**: Use the topographic horizon line from the ***meteonorm*** server. This requires a working internet connection. The software searches for the horizon line served by an internet horizon server provided by ***METEOTEST***. This online horizon information is provided for all regions of the world between 60°N and 60°S using a 90 m digital terrain model. The coverage is visualized on http://meteonorm.com/download/horizon/.

- **Use custom**: Use a horizon line edited with the horizon editor.



The button *Edit horizon...* will open the horizon editor which allows drawing your personal horizon line.



The horizon editor allows modifying the horizon line according to the local neighborhood. The green area at the bottom shows the horizon of the surrounding landscape retrieved from the horizon server. The topographical horizon can be calculated for all regions of the world between 60°N and 60°S using a 90 m digital terrain model. This normally gives quite a good approximation of the horizon line. If the horizon is very near (e.g. the site is on a slope) the horizon is shown as blocks. The thick red line shows the final horizon line which is a mixture of the topographical horizon and the custom horizon. The topographical horizon is used as a base horizon line. With left mouse clicks you can add the custom horizon line from additional nearby objects like buildings or trees. Points are marked as black squares. Remove points with right mouse clicks or by dragging the points out of the window. In the example above, a skyscraper in the neighborhood is added to the topographical horizon.

Horizon editor functions

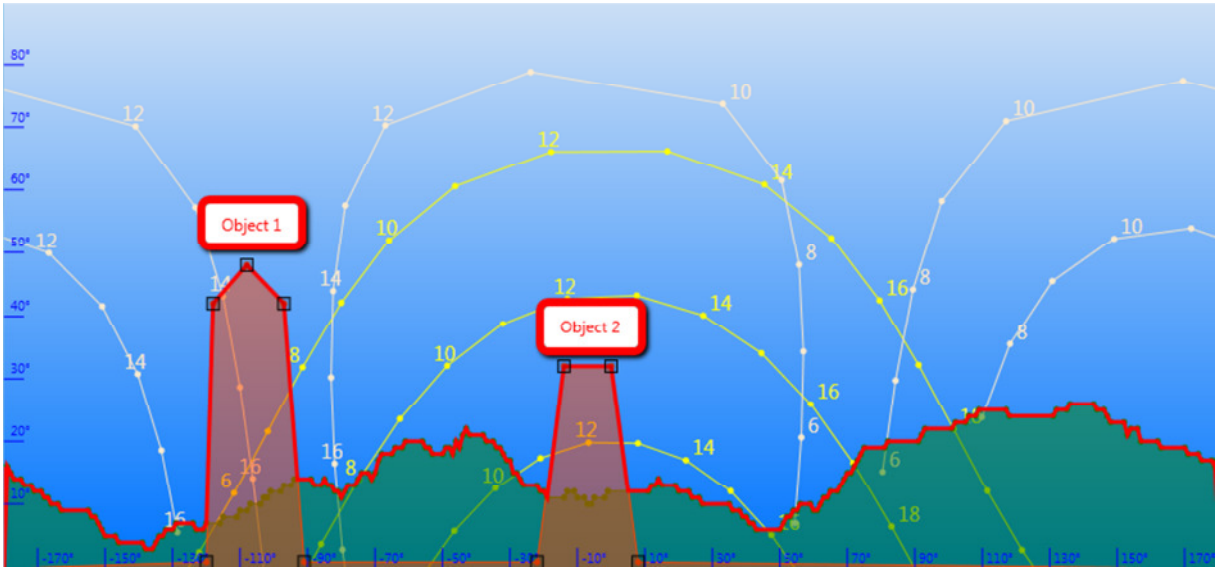
- **Background image**: If you have a 360° image of the surrounding of your location e.g. made with ***meteonorm horicatcher***[1], geological compass, theodolite or fish-eye camera, you can load this image into the editor as a background image for more precise digitizing of the horizon line. The image can be imported in jpg or png format. The image must stretch from N to W, S, E to N again (azimuth from +180° to -180°) and from 0° to 90° elevation.
- **Display**: A legend of the different colored lines in the image is given. Checkboxes are used to switch on/off the topographical horizon, to display the sun paths for winter solstice, spring/autumn and summer solstice and to display the reflections of a solar panel according to the plane orientation.
- **Horizon**: You can load a horizon line from a previously stored *.hor file. You can save the horizon line as a *.hor file. The data are stored with a 1° resolution. The button *Remove custom horizon* will delete the custom set points. The topographical horizon remains.
- The **opacity slider** changes the transparency of the green topography layer.

[1] see http://www.meteonorm.com/products/meteonorm-horicatcher/

For fixed hourly output formats (DOE, TMY2, TRY etc.), the global radiation is corrected for the horizon profile (e.g. the selected raised horizon is included in the calculation) and written to the output. For standard and user-defined output formats, radiation on inclined planes (Gk and Dk) is corrected for horizon profile, but not radiation on the horizontal plane (Gh and Dh). Gh and Dh are calculated with an astronomical horizon and written unmodified to the output.

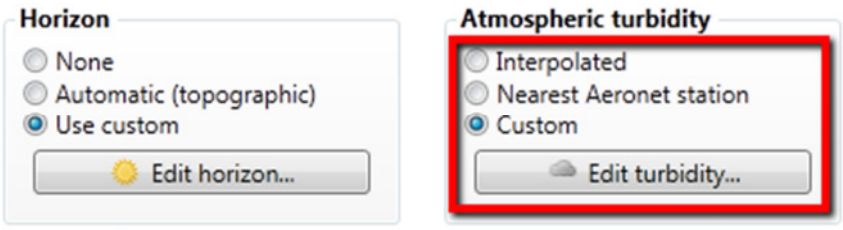
Horizon Example

In the example below we have drawn the topographical horizon plus two objects in the nearby neighborhood. We have a setup of a solar panel oriented -40° azimuthal and 20° inclined. The sun paths show us that we have shading from object 1 in the early morning hours in summer and shading from object 2 at noon in winter. In spring and autumn we will have reflections from the panel at object 1 in the afternoon.

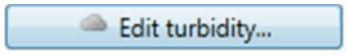


Atmospheric turbidity

The part of the solar radiation reaching the ground is influenced by the turbidity of the atmosphere. ***meteonorm*** uses the concept of the Linke turbidity factor. Turbidity information in ***meteonorm*** is based on a mixture of satellite data from the satellite experiments MISR and MODIS and ground station measurements from Aeronet. More theoretical details about the turbidity are described in the ***meteonorm*** Theory Manual in chapter 6.5.3.



The selection can be made whether to use the interpolated satellite data (default) from ***meteonorm***, from the nearest Aeronet station (ground data) or to use user modified values.



The button *Edit turbidity...* opens the turbidity editor which allows entering your own turbidity values.

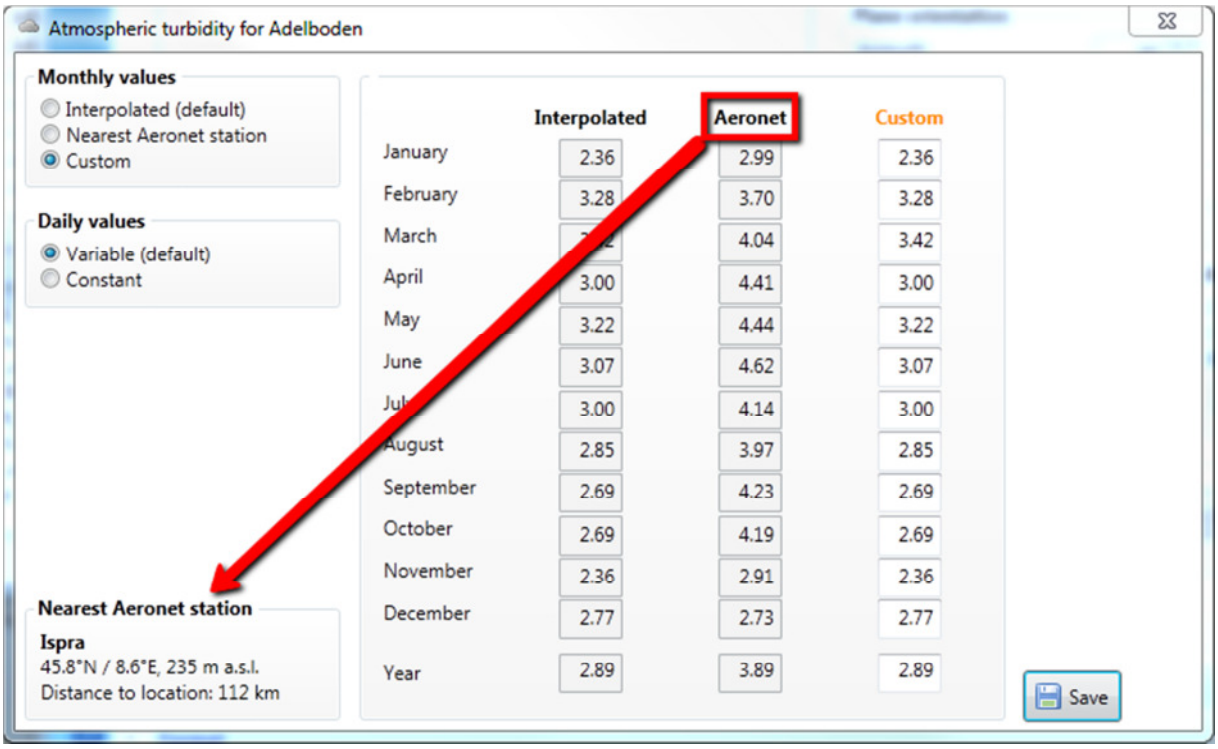


Fig 2. Set custom atmospheric turbidity values.

Turbidity editor functions

- Monthly values: Choose between three datasets of monthly values. The selected one will be marked in orange in the value table on the right side. *Interpolated* interpolates the values from the ***meteonorm*** turbidity climatology. *Aeronet* is from a ground station network. The nearest site is shown by following the red arrow in the image above. *Custom* lets you enter your personal values.
- Daily values: Select 'Variable (default)' for variable values on a daily basis. To hold them constant throughout the month select 'Constant'.

Data import

There are different types of data imports:

- Import of **current monthly values** for a specific year through the ***meteonorm*** data webservice. Hourly values will be generated from these by ***meteonorm***.
- You can enter **your own monthly values** and make a simulation with them. This is described in more detail in chapter 2.4.
- Import of **your own hourly values**. You can import your hourly values. They will be passed through the ***meteonorm*** processor. Additional parameters will be added by meteonorm if needed depending on the output format. This is described in more detail in chapter 2.4.

The import of monthly values is useful e.g. to

- make a simulation of the weather for your own monthly values.

- add additional monthly values to the database. These monthly values can also be used for interpolation if the location has been defined as a *User (month)* site.

In case of importing hourly values, this is useful e.g. to

- transform data files from one data format to another
- do calculations on inclined planes if you only have global radiation horizontal values

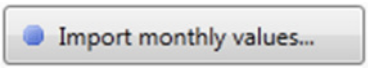
Import of current values from the ***meteonorm*** server

Current monthly data can be imported automatically. By pressing the button *Current data*, the period can be entered (1–12 months) and the data (radiation and temperature, for Switzerland also temperature distributions) is downloaded automatically from a server operated by ***METEOTEST***. Data is always interpolated. The data exists from 1998 onwards. Data will be available approx. 2 weeks after the end of each month.

The quality of the data is specified in 4 levels:

- High: Near station with current data available or interpolation within Switzerland (from 2001 onwards). In Switzerland, data with corrections for horizon and location influences are available since 2001.
- Middle: More than 3 stations available for interpolation (normally nearer than 500 km). Satellite data available (from October 2006 onwards).
- Low: Less than or equal to 3 stations for interpolation.
- Not available: No station nearer than 2000 km, no other data source.

Example

1. Push the button '*Import monthly values...*'. 

2. Select the start of your desired year. In the example April 2011 is selected which will retrieve the values from April 2011 to March 2012.
3. Push the button '*Download*'.

4. The table will be filled with values. On the right you will see information about the data quality.
5. To continue with ***meteonorm*** push the '*Save*' button.

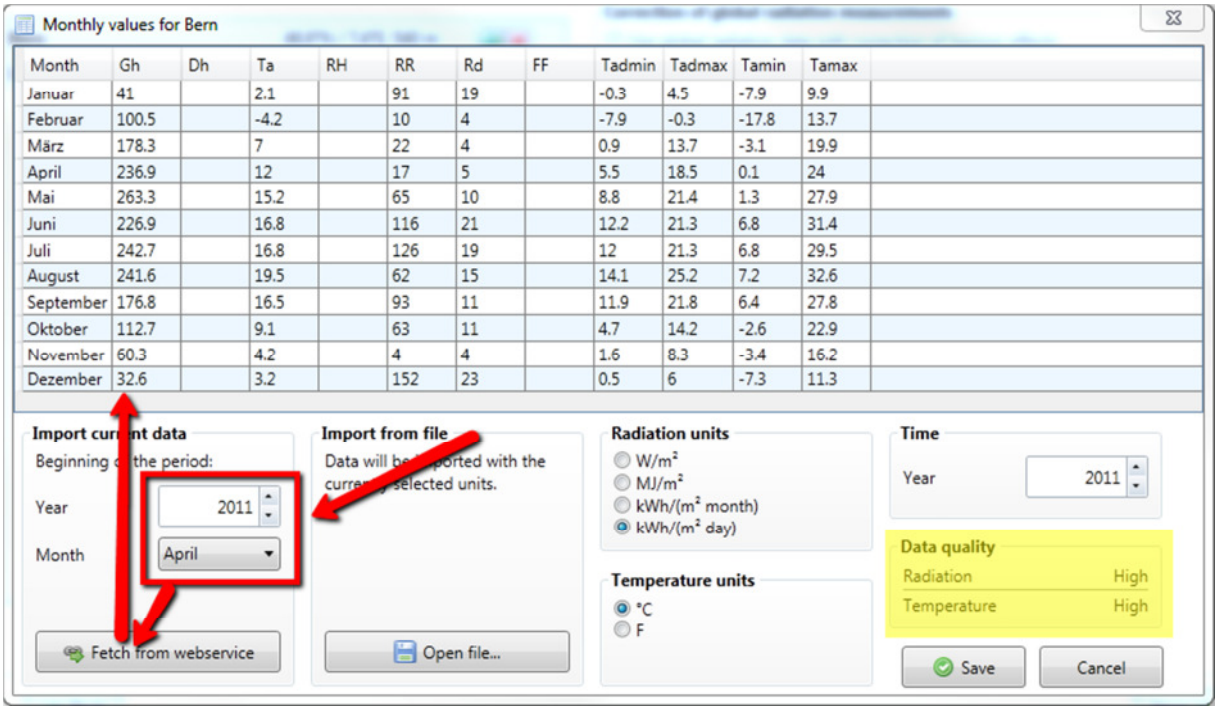
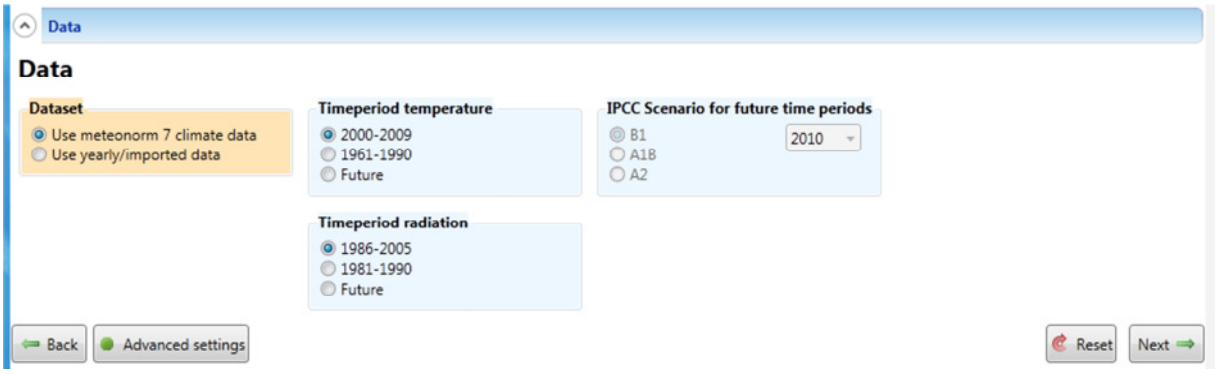

Monthly values for Bern
Month Gh Dh Ta RH RR Rd FF Tadmin Tadmax Tamin Tamax
Januar 41 2.1 91 19 -0.3 4.5 -7.9 9.9
Februar 100.5 -4.2 10 4 -7.9 -0.3 -17.8 13.7
März 178.3 7 22 4 0.9 13.7 -3.1 19.9
April 236.9 12 17 5 5.5 18.5 0.1 24
Mai 263.3 15.2 65 10 8.8 21.4 1.3 27.9
Juni 226.9 16.8 116 21 12.2 21.3 6.8 31.4
Juli 242.7 16.8 126 19 12 21.3 6.8 29.5
August 241.6 19.5 62 15 14.1 25.2 7.2 32.6
September 176.8 16.5 93 11 11.9 21.8 6.4 27.8
Oktober 112.7 9.1 63 11 4.7 14.2 -2.6 22.9
November 60.3 4.2 4 4 1.6 8.3 -3.4 16.2
Dezember 32.6 3.2 152 23 0.5 6 -7.3 11.3
Import current data
Beginning of the period:
Year 2011
Month April
Fetch from webservice
Import from file
Data will be imported with the currently selected units.
Open file...
Radiation units
W/m²
MJ/m²
kWh/(m² month)
kWh/(m² day)
Temperature units
°C
F
Time
Year 2011
Data quality
Radiation High
Temperature High
Save
Cancel

Fig 2.: Import of current monthly values for one whole year by internet. Set the starting month and push the button *'Download'*.

2.3.2.4 Step 3: Data

In the Data window you can modify the setting for the data and the models applied to the data.

Basic Settings



In the basic settings you can define which data basis and which time period will be used for the calculations.

Dataset

The dataset field (in orange) specifies whether to use the ***meteonorm 7*** climate database or to use the imported data from the data import in the modification part in the step before. When selecting Use imported data neither the provided time periods nor a future scenario can be chosen.

Time period for temperature / radiation

The time period can be chosen on one hand for the radiation parameters (radiation) and on the other hand for temperature and all the other parameters. Two climatological time periods are available for both groups as well as a future time period for a climate change scenario:

- Temperature (and all other parameters except for radiation): 1961–1990 and 2000–2009
- Radiation: 1981–1990, 1986–2005
- Future: By selecting *Future* the field *IPCC Scenario for future time periods* is activated. There you can choose between different scenario types which affect the climate differently. More details about this topic are given in chapter 3.2 Climate change data.

The 2000–2009 period for temperature and the 1986–2005 period for radiation depict the periods most commonly used. At some stations, the periods can differ from these standard periods. By opening the information window of a weather station in the Locations part you can see which data is available and from which period it is. For *Cities* or *User defined* sites the radiation period of cannot be chosen. The radiation values are pre-interpolated for these sites. For this interpolation a database including global radiation measurements of all time periods is used.

Advanced settings

Advanced settings are intended for more experienced users, as they allow changing the standard setting by selecting different radiation models or other specific settings. By changing the defaults the green dot on the button "Advanced settings" changes to yellow. By pushing the Reset button all settings in the Data step are reset to their default.

Radiation model

- **Default (hour).** Hourly values for one typical year are generated. The chain of algorithms from (Remund, 2008) is used. See chapter 6.8.1 in the theory manual for details.
- **Minute (Aguiar & Collares-Pereira).** Minute values for one year are generated according the TAG model. See chapter 6.8.1 in the theory manual for details.
- **Minute (Skartveith & Olseth).** Minute values for one year are generated according Skartveith and Olseth (1991). See chapter 6.8.1 in the theory manual for details.
- **Clear sky radiation**: Calculation of maximum global radiation and corresponding diffuse radiation for clear days (cloudless sky) at hourly intervals. This affects the automatic selection of the clear day temperature model (warmest possible temperature).
- **Monthly variation**: This will produce a more variable year instead of a typical mean year. The monthly values are not the mean of the selected climatological period but are varied between the climatological extreme boundaries.
- **10 years**: This will generate 10 single years of the 'monthly variation' type. 10 files are written to the output (10 x 8760 values).

For minute data only the special output format "Standard Minute" and "PVScout" will be available in the settings of the Output step. Only the radiation parameters are generated in minute resolution. The other parameters will be generated in hourly resolution.

Diffuse radiation model

You have the choice between two models for the calculations of the diffuse and direct part of the radiation. See the theory manual for further details.

- **Perez (default):** This is the standard model which was already used in *meteonorm* version 6. (Perez, 1991)
- **Boland/Ridley/Lauret (BRL):** Added in version 7.0. (Ridley, 2010)

Temperature model

- **Standard (hour):** The default model for hourly temperature values produces hourly extremes, which correspond to mean extreme values.
- **10 year extreme (hour):** This model for hourly temperature values produces hourly extremes, which correspond to 10 year hourly extreme values. This option will spread the distribution of values while the climatological mean remains the same. It is suited for simulations in which also extremely warm or cold values have to be considered (e.g. building simulations).
- **Clear sky temperature:** This model is selected automatically when the clear sky radiation model is chosen and cannot be selected by the user himself.

Tilt radiation model

The Perez model is the default model. Three further models are optionally available for the calculation of radiation on tilted planes.

- **Perez (1986):** This is the default model. It delivers the most robust and best results for generated time series.
- **Hay's model (1979):** This delivers slightly better results for vertical surfaces than the Perez model.
- **Skartveit and Olseth** model (1986)
- **Gueymard's** model (1987)

See chapter 6.7.2 for test results.

First random seed

10 different first random numbers of the generation algorithm of hourly radiation can be chosen. By changing this number, different time series of all meteorological parameters are generated due to a different initialization of the stochastic process. The monthly means remain the same.

Time system

Definition of the time system in which the data is saved.

- **Legal:** The data is saved in local winter time.
- **Solar:** The data is saved in true solar time which means that the highest sun elevation angle is always at noon.

10 year monthly extreme values for temperature and radiation

For the analysis of radiation and temperature extremes at the selected location there is the possibility to simulate rare climate events. The option allows displaying the variations at a certain location.

- **Averages (default)**: Per default an average year is generated.
- **Monthly minima/maxima** will take the lowest/highest monthly values for a decade.
  Attention: This is not equal to a P90/P10 extreme year. These are even a much rarer events.
- **Yearly minima/maxima** will produce a yearly value with a statistical probability of happening once in a decade (minima = P10, maxima = P90). This allows evaluating a P10 or P90 year. P10 means that there is 10% chance to have such a year or such a year occurs once in 10 years. P90 will occur 9 times in a decade.

- **Summer/Winter** allows selecting summer and winter periods specifically. With this function you can produce e.g. a cold winter together with a hot summer which is a worst case scenario for heating and cooling simulations.

Extremes can be simulated for temperature and global radiation only.

For radiation the 10 year extreme monthly values of the 6 nearest measurement stations are interpolated to obtain the extreme conditions for each location.

For temperature the extreme values are calculated using the standard deviation of the interpolated 6 nearest sites with such measurements. For the maximum values the standard deviations, multiplied by the factor 1.28, are added to the mean, for the minimum values the standard deviations are subtracted. The annual mean resulting this way does not correspond to any realistic value, because 12 ten year extreme months are not probable to follow each other.

Output format specific settings

For the output format PHPP/WaVE the parameters for calculating the heating and cooling degree days can be modified.

Heating loads:

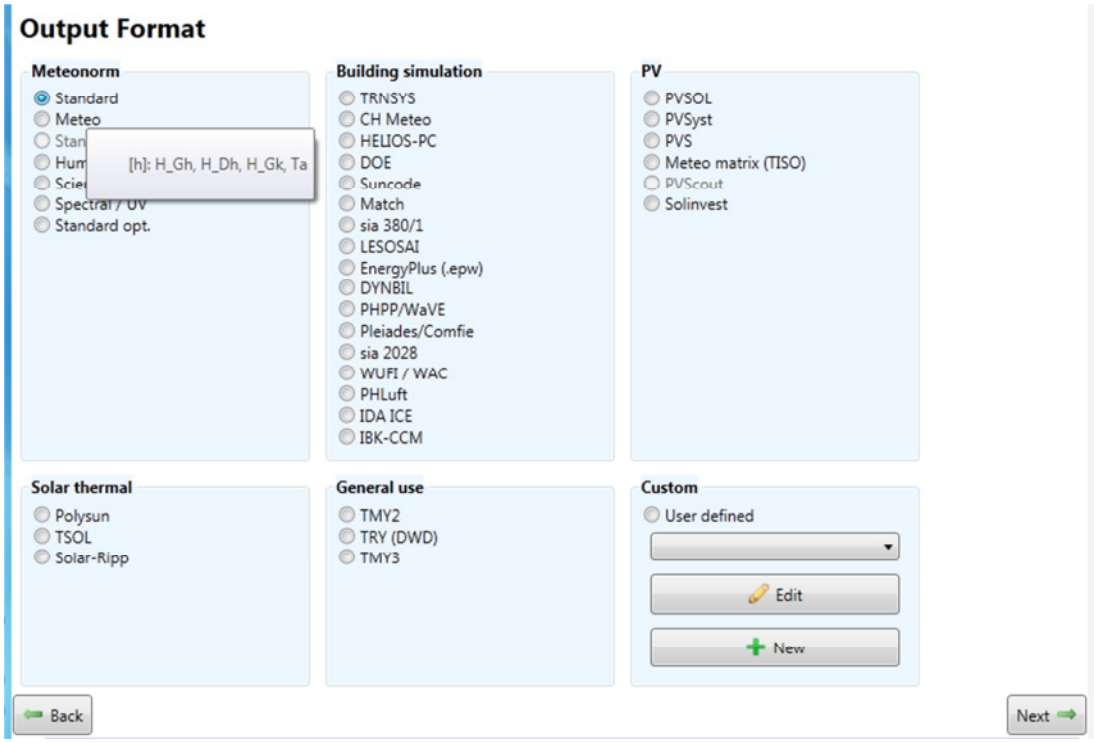
- **Number of cold days**: equals the number of days in which a building cools down or is heated up.
- **Critical temperature Inside**: Aspired room temperature inside the building.
- **Critical temperature Outside**: Above this outside daily mean temperature heating is not needed any more.
- **Average hours above**: Number of hours to calculate minimum temperature to satisfy the comfort criteria (e.g. 12 = 12-hours minimum is calculated)

Cooling loads:

- **Number of hot days**: Equals the number of days in which a building heats up (in summer).
- **Critical temperature outside**: Above this outside daily mean temperature cooling is needed.
- **Night ventilation limits**: Limitations of temperature and humidity to use night time cooling based on ventilation.

2.3.2.5 Step 4: Format

The Format window defines which final data will be stored to a file and the output data format. 36 predefined data formats are available. Beside some data formats defined by ***meteonorm***, or generalized data formats like the Typical Meteorological Year (TMY) there are a lot of data formats designated for data exchange with specific software packages for building simulations or solar energy applications. In Tables 2.3.2 to 2.3.6 the parameters and units calculated for the respective formats are given. The naming of the data format is given by the name of the external software, e.g. the data format for the software PVSOL is named PVSOL. The data exchange formats for the external simulation software have been specified and tested together with the developers of the corresponding software. Additionally you can define your own output format with the 'User defined' data format (see subsection 'User defined data format' below).



Moving the mouse over a data format will activate a tool tip showing the parameters stored in this format. This is demonstrated in the image above. The tool tip first shows the time step the data is stored in in brackets ([h]: hourly, [min]: minutely, [mon]: monthly) and then the list of the parameter abbreviations. Parameters and their abbreviations are described in detail in chapter 5.

If you choose the standard or the user-defined output, you are free to choose any desired surface orientation. If you select a fixed format for a particular simulation software, the surface orientation and also the units may be disabled, as these settings will be applied in the simulation software itself.

Tab. 2.3.2: Definition of designated ***meteonorm* output formats**: Number and sequence of parameters. Symbols: y: year, m: month, dm: day in month, dy: day in year, h: hour, hy: hour in year. The remaining symbols are defined in chapter 5.

Format	time-step	Header lines	Parameters	Delimiter	Units
Standard	hour	-	m, dm, h, hy, G_Gh, G_Dh, G_Gk, G_Dk, G_Bn, Ta	Tab.	[W/m²], [°C]
Meteo	mon	5	Ta, Ta_{min}, Ta_{dmin}, Ta_{dmax}, Ta_{max}, RH, H_Gh, SD, SD_{astr}, RR, RD, FF, DD, snow and wind loads	Blank	[°C], [%], [W/m²], [h/day], [mm], [days], [m/s], [deg]
Standard minute	min	-	m, dm, dy, h, min, G_Gh, hs, G_G_{ex}, G_Gh (hour), G_Dh, G_Gk, G_Bn, Ta, FF	Tab.	[W/m²], [°C]
Humidity	hour	-	m, dm, h, hy, G_Gh, Ta, Td, RH, Tp, mx, PP, Enthalpy, RR	Blank	[W/m²], [°C], [hPa], [mm]
Science	hour	-	m, dm, dy, h, Ta, G_Gh, Td, RH, G_Dh, FF, DD, G_Lin, RR, Sd, N, hs, TL, G_Bn, G_Gc, G_Dc, G_ex, G_Gh profile, PAR, snow, G_Lup	Blank	[W/m²], [°C], [%], [m/s]
Spectral /UV	hour	-	m, dm, h, hy, G_Gh, G_Dh, Ta, UVAc, UVBc, UVEc, UVA, UVB, UVE, UVAincl, UVindex	Blank	[W/m²], [°C]
Standard/opt.	mon	-	H_Gh, H_Dh, H_Gk (optimum inclination), Ta	Blank	[W/m²], [°C]

Tab. 2.3.3: Definition of **output formats for Building simulation** software.

Format	time-step	Header lines	Parameters	Deli-miter	Units
TRNSYS	hour	2	dm, m, h, G_Bh, G_Dh, Ta, FF, RH	Blank	[W/m²], [°C], [m/s]
CH-METEO	hour	-	Any Number, y, dy, h, FFE, FFN, Ta, RH, p, RR, G_Gh, Sd, FF, Td, Tp, N	Tab	[W/m²], [°C], [m/s], [cm], [h], [hPa]
HELIOS-PC	hour	-	y, dy, dm, m, h, G_Gh, G_GvE, G_GvS, G_GvW, G_GvN, G_Dh, G_Lin, G_Lv, Ta, RH, FF, FFaS, FFaW, FFaN, FFaE, G_Bn	Blank	[W/m²], [°C], [%], [m/s]
DOE	hour	-	Any Number, Ta, Tp, Td, DD, FF, p, Wc, N, N1a, N1, G_Gh, G_Bn, G_Dh, y, m, dm, h	Blank	[btu/ft² h], [F], [1/100 inch Hg]
SUNCODE	hour	-	G_Bn, G_Gh, Ta, Td, FF	Blank	[kJ/m² h], [1/10 °C], [1/10 m/s]
MATCH	hour	-	Ta, Td, G_Gh, G_Dh, G_Bn, N, FF	Blank	[W/m²], [1/10 °C], [kt]
sia 380/1	mon	-	Ta, H_GvS, H_GvE, H_GvW, H_GvN, HD_{10}, $HDD_{18/10}$, HD_{12}, $HDD_{20/12}$, HD_{14}, $HDD_{22/14}$, snow and wind loads	Blank	[MJ/m²], [°C]
LESOSAI	mon	-	Ta, H_GvS, H_GvE, H_GvW, H_GvN, HD_{10}, $HDD_{18/10}$, HD_{12}, $HDD_{20/12}$, HD_{14}, $HDD_{22/14}$, FF, RH	Blank	[MJ/m²], [°C], [m/s], [%]
ENERGY PLUS** (epw files)	hour	8	m, dm, h, Ta, Td, RH, p, G_G_{ex}, G0, G_Gh, G_Bn, G_Dh, LG, LD, L_Z, DD, FF, N, N1, Vis, Hc, Wc, w, Aod, Sn, Ds**	Blank	[W/m²], [°C], [m/s], [cm], [h], [hPa]
DYNBIL	hour	11	m, d, h, min, Ta, RH, Ts, FF, DD, G_Lin, G_Dk, G_DirX, G_DirY, G_DirZ	Blank	[°C], [W/m²], [m/s]
PHPP/WaVE	hour	2	Ta, H_GvN, H_GvE, H_GvS, H_GvW, H_Gh, Td, Tsky, FF	Blank	[W/m²], [°C], [m/s]
Pleiades/ Comfie	hour	0	Any Number, Ta, H_Gh, H_Dh, H_Bn, Sd, RH, FF, m, dm, h	Blank	[1/10°C], [J/cm²], [min.], [%], [1/10 m/s]
sia 2028***	hour	1	Nr, y, m, d, h, Ta, p, RH, RR, FF, FX, DD, T_{ground}, N, G_Gh, G_Dh, G_Bn, G_GvE, G_GvS, G_GvW, G_GvN, rho, G_Lin, G_LvS, eh, Td, enthalpy, mx, Tp	Tab.	[°], [m/s], [mm], [hPa] [°C], [%], [W/m²]
WUFI / WAC	hour	12	G_{Gh}, G_{Dh}, N, Ta, Rh, FF, DD, RR, G_{Lin}	Tab	[W/m²], [°C], [m/s], [mm], [%]
PHLuft	hour	4	Ta	Blank	[°C]
IDA ICE	hour	1	Ta, Rh, FFE, FFN, G_Bn, G_Dh	Tab	[°C], [%], [m/s], [W/m²]
IBK-CCM	hour		Ta, Rh, G_Bh, G_Dh, G_Lup, G_Lin, n, DD, FF, RR (one file per parameter)	Blank	[°C], [%], [m/s], [W/m²]

Tab. 2.3.4: Definition of **output formats for PV simulation** software.

Format	time-step	Header lines	Parameters	Deli-miter	Units
PVSOL	hour	4	G_Gh, Ta, RH, FF	Tab.	[W/m²], [°C], [%], [m/s]
PVSYST	hour	6	G_Gh, G_Dh, Ta, FF	Blank	[W/m²], [°C], [m/s]
PVS	hour	6	G_Gh	Blank	[W/m²]
Meteo Matrix	hour	1	G_Gh, Ta (classified in form of matrix)	Tab	[W/m²], [°C]
Pvscout ****	hour	12	G_Gh T_{module}, (distribution in minute time resolution)	Semi-colon	[W/m²]
Solinvest	hour		m, d, h, hy, G_Gh, G_Dh, G_Bn, Ta	Semi-colon	[W/m²], [°C]

Tab. 2.3.5: Definition of **output formats for solar thermal simulation** software.

Format	time-step	Header lines	Parameters	Deli-miter	Units
Polysun	hour	4	hy, G_Gh, G_Dh, Ta, G_Lin, FF, RH	Semi.	[W/m²], [°C], [m/s]
TSOL	hour	4	G_Gh, Ta, RH, FF	Tab.	[W/m²], [°C], [%], [m/s]
Solar-Ripp	hour	-	G_Gh, Ta, RH, FF, G_Lin (plus binary format)	Blank	[W/m²], [°C], [m/s], [%]

Tab. 2.3.6: Definition of **generally used output formats**.

Format	time-step	Header lines	Parameters	Deli-miter	Units
TMY2**	hour	1	m, d, h, G_G_{ex}, G0, G_Gh, G_Bn, G_Dh, LG, LD, L_Z, N, N1, Ta, Td, RH, p, DD, FF, Vis, Hc, Wc, w, Aod, Sn, Ds**	Blank	[W/m²], [°C], [m/s], [cm], [h], [hPa]
TRY (DWD)	hour	24	Any Number, dm, m, h, N, DD, FF, FFv, Wc, RR, p, Ta, RH, G_Bh, G_Dh, LG, G_Lin, G_Lup	Blank	[°], [m/s], [mm], [hPa] [°C], [%], [W/m²], [lux]
TMY3**	hour	2	m, d, h, G_{Go}, G_{ex}, G_{Gh}, G_{Bn}, G_{Dh}, L_G, L_{Bn}, L_D, L_Z, N, N1, Ta, Td, RH, p, DD, FF, Vis, Hc, Wc, w, Aod, albe-do, lprec	Tab	[W/m²], [°C], [m/s], [cm], [h], [hPa]

*: For a horizontal surface, H_{Gk}, H_{Dk} and H_{Bk} are replaced by H_{Bh}, and G_{Gk}, G_{Dk}, G_{Bk} by G_{Bh}.

** Special parameters for TMY2/3 and Energy Plus (not calculated): L_Z: Zenith Luminance; N1: opaque sky cover (calculated with linear regression from N); Vis: Visibility, Hc: Ceiling Height; Wc: Current Weather; Aod: Aerosol Optical Depth, Sn: Snow Depth; Ds: Days since last snow-fall, lprec: liquid precipitation depth

*** www.energycodes.ch , eh: ground emissivity

**** www.solarschmiede.de

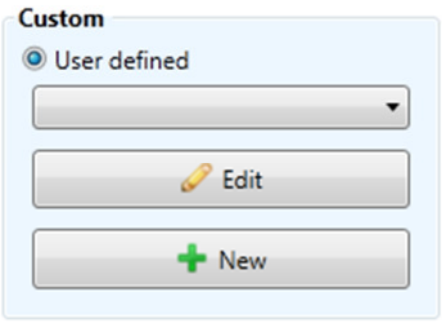
User defined data format

You can define a data format yourself. You choose the parameters, units and the delimiter symbol yourself. The user defined format is stored for later usage. The single format definition files are stored as files with the extension *.muf in the folder

c:\Users\<username>\AppData\Roaming\Meteotest\meteonorm7\CustomFormats\.

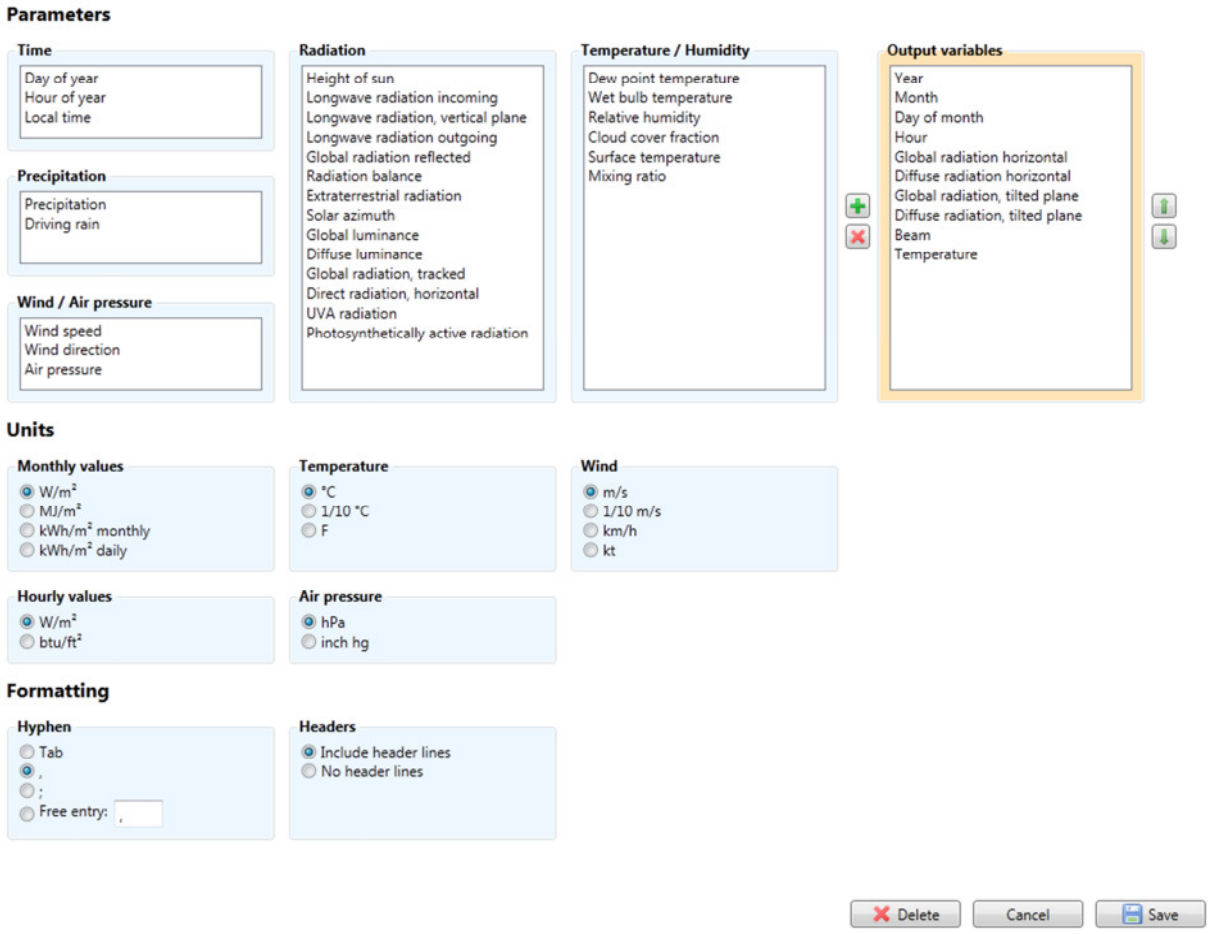
In ***meteonorm*** version 6 the user defined formats were stored in files with the extension *.muf. These *.muf files can be imported for usage in version 7.

The default units for radiation are [kWh/m²] for monthly values, and [W/m²] for hourly values. The default unit for the temperature is [°C]. If you subsequently select a fixed output format, the units will be reverted to their fixed values. A header with four lines can be activated. The first line contains the name of the site, the second line the latitude and longitude, height above sea level, time zone and elevation and azimuth of the plane (if elevation is greater than 0°). The third line is blank, and the fourth line contains the parameter headings.



Select
From the drop down list you can select one of your previously defined data formats. Once you have selected a data format from the list, you can edit it by clicking on the *Edit* button.

Create
To create a new data format click on the *New* button. A dialog window asks you to enter a name for your format. This will become the filename and the name shown in the dropdown list. A new window will open. You can select a parameter by double clicking on it (or select and push the green plus button). This moves the parameter to the output box (highlighted with an orange border) on the right hand side. To remove a parameter, double click on it in the output box (or select and click the red cross button).



Delete

To delete a user defined format, select it from the drop down list, click Edit and then click the Delete button (Delete) at the bottom.

Additional information for some data formats

When using the **DOE** format, an additional file for ground temperatures is written. The additional DOE file has the same name as the output file, but the extension *.DOE. With version 7.0 the packing of the data into a binary file is not possible any more. Read in the following paragraph '*Software without data exchange formats with* ***meteonorm***' under the point eQuest howto produce a binary file for DOE.

Meteo provides an overview of the meteorological parameters of a site as monthly values.

Standard/opt. calculates the optimal angle of panel inclination for the site. ***meteonorm*** evaluates the optimal azimuth and inclination angle with the highest radiation income in steps of 5°.

PHPP/WaVE calculates the heating and cooling loads. Five different stochastic runs are carried out. The calculation of design temperatures for cold and cloudy situations is based on the cloudiest period. The design temperatures can be adopted statistically in order to correct the bias (which is recommended as it reduces uncertainty). Beside a calculation based on long term monthly means, a worst case calculation is also carried out. This calculation is based on 10 year extremes (cloudy, cold winters and sunny, hot summers).

TMY3 includes aerosol information shown is based on the ***meteonorm*** turbidity information (also for original DRY / TMY3 sites). Columns with uncertainties in this data format are reported for all sites identically: 10% for global irradiation and 20% for beam irradiation. For the meteorological parameters the flag E and the uncertainty level 8 is set.

Software without data exchange formats with *meteonorm*

LightTools from Optical Research Associates

This software delivers its format specifications in form of a User defined format (*.muf file) included in its software package distribution. This file needs to be imported for correct data output. Please follow the instructions given by the user manual of LightTools.

Ecotect Analysis from Autodesk, Inc.

For this software *.WEA (weather data files) files are required. There is a possibility to convert EnergyPlus (*.epw) files into *.WEA files. Follow the instructions given by:
http://wiki.naturalfrequency.com/wiki/Converting_EnergyPlus_Weather_Data

Designbuilder from DesignBuilder Software Ltd

EnergyPlus (*.epw) or TMY2 data format can be imported into Designbuilder.

eQuest

For data import into the software eQuest, use binary files generate in the DOE data format.

As a second option you can generate an EnergyPlus (epw) file and use the tool eQ_WthProc (http://doe2.com/index_wth.html) from DOE to convert it to a DOE binary file. If you receive the error message *'invalid floating point'*, it is related to the regional and language options from the Windows operating system. Go to 'System settings' → 'Change date, time, number, currency value settings' → Click the 'Customize this format' button → Set the *decimal symbol* to dot (.) and the *digit grouping symbol* to comma (,).

Trane Trace

This software can import weather files in the TMY2 and TMY3 data format.

SMA Sunny Design

This software accepts the ***meteonorm*** standard output format and the EnergyPlus (epw) format.

IES (Integrated Environmental Solutions) Virtual Environment

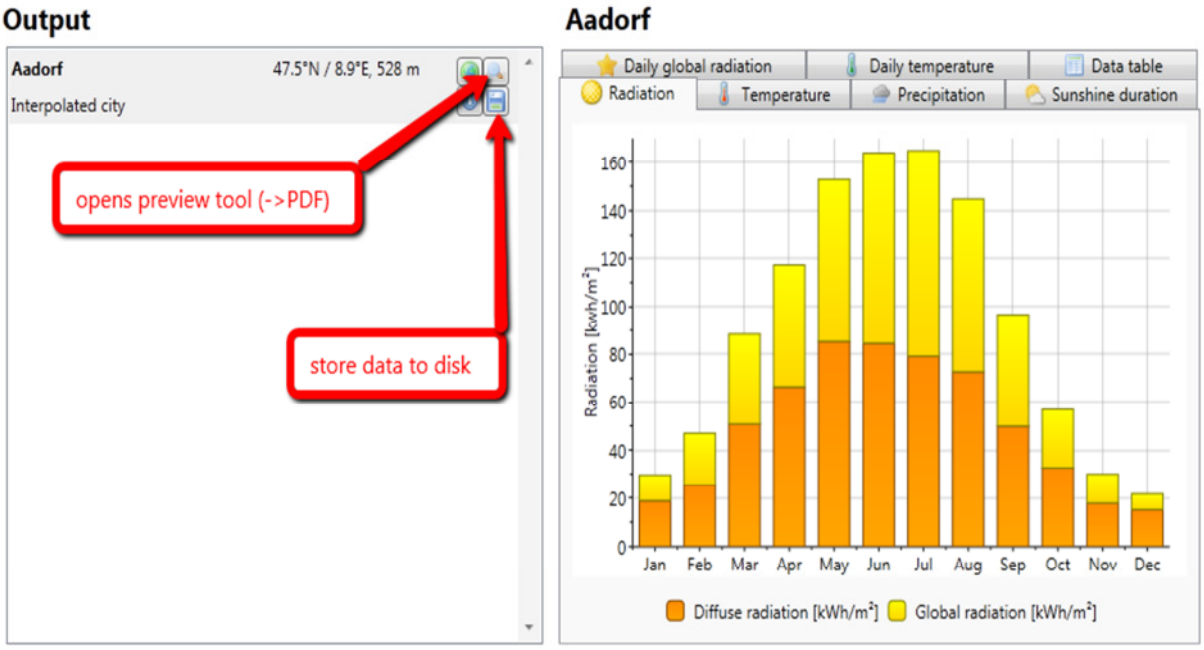
This software accepts the EnergyPlus (epw) format.

EDSL Tas

This software accepts the EnergyPlus (epw) and TMY2 format.

2.3.2.6 Step 5: Output

On the right hand side of the output window, graphs of the calculated results are shown. Monthly values of radiation, temperature, precipitation and sunshine duration are shown as well as the curves for daily global radiation and temperature.



On the left hand side of the window you can store your results by clicking the appropriate icons of the selection toolbox. The **magnifier icon** will open the preview sheet which can be stored as a PDF file.

The graphs presented in the output part as well as a table with the monthly values are included in the PDF. Additionally, the nearest sites (up to three sites with the distance to each one of them) or the WMO number for weather stations which were used for the interpolation are shown. Furthermore, information on the uncertainty of the yearly value for radiation and temperature as well as the trend and the year to year variability of the global radiation is provided. The **floppy disk icon** lets you store the data as ASCII files. You will be prompted for the time resolution to store the data. The data is stored according to the data format selected in the format window. The **icons on the left hand side** (green globe and information) show information (e.g. coordinates) about the selected location.

The hourly files may contain very different parameters depending on the selected output format. The parameters and the parameter order are shown in Tab. 2.3.2. Hourly files consist of 8'760 lines. Each line contains the values for one hour.

The monthly files contain a table with the values and information about the setting used as well as information about the nearest three stations used for the interpolation procedure and uncertainty information for radiation and temperature.

2.3.2.6 Uncertainty, variability and trend information

The uncertainty model of meteonorm 7 is described in chapter 7.3 of the theory handbook.

The measurement uncertainty (as part of the uncertainty model), the variability and trend information is taken from the 6 nearest stations with long term measurements (subset of GEBA database with approximately 800 stations). The same interpolation method as for the other meteorological parameters is used (see chapter 6.2.1). Only results are given, if the nearest GEBA station is closer than 1500 km.

2.3.2.7 Interpretation of the results

Do not interpret the 1st of January as THE mean 1st of January but as a day in January. Values within a month are realistic values for that month based on the statistics and variations of the data of nearby measurement stations for that month.

meteonorm is tuned to the parameters global radiation and temperature. Do not make wind assessments with ***meteonorm***.

2.4 Import of your own data

meteonorm allows the user to import their own monthly and hourly data.

2.4.1 Monthly values

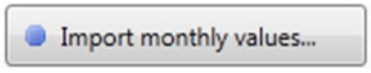
2.4.1.1 CSV import

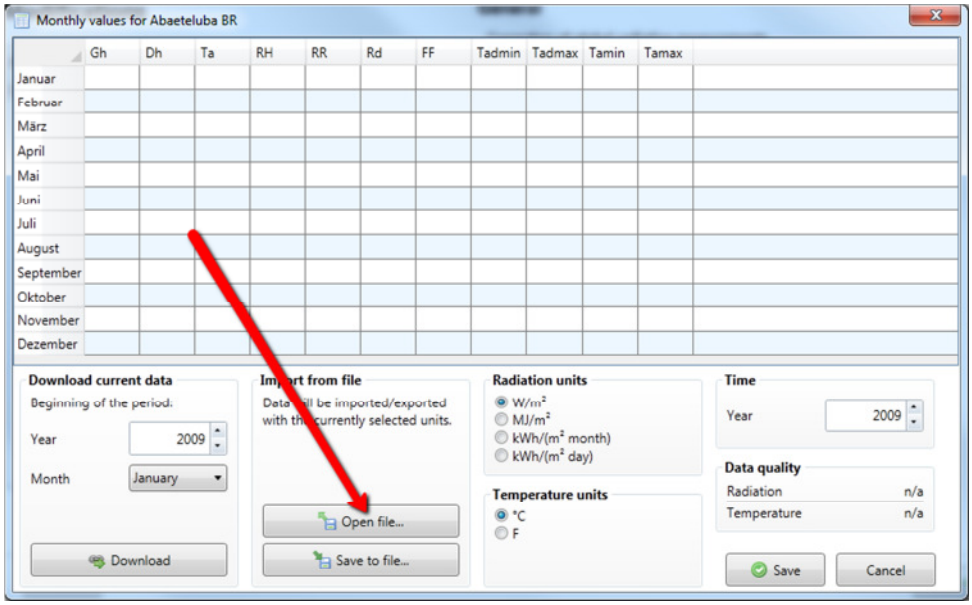
In ***meteonorm*** version 7 monthly values are imported as a CSV (Character Separated Values) file. The delimiter can be a semicolon (;) or a tabulator. One header line is needed specifying the parameters abbreviations followed by 12 lines – one for each month – containing the data. The first column is reserved for the month. The columns with the meteorological parameters are optional and do not have a specified order. Fill out missing values for single months with -999. Missing parameters will be filled with the climatological mean.

Tab. 2.4.1: Parameters for monthly data import. The timestamp (Month) is mandatory, all other parameters are optional.

Abbreviation	Parameter	Unit
Month	Month	
Gh	Global radiation horizontal	[kWh/m² month]
Dh	Diffuse radiation horizontal	[kWh/m² month]
Ta	Temperature	[°C]
RH	Relative humidity	[%]
RR	Precipitation	[mm]
Rd	Days with rain	[days]
FF	Wind speed	[m/s]
Tadmin	Mean daily minimum of temperature	[°C]
Tadmax	Mean daily maximum of temperature	[°C]
Tamin	Minimum hourly temperature	[°C]
Tamax	Maximum hourly temperature	[°C]

To import the CSV file go to register *modification*, click on "*Import monthly values*" and then on "*Open file...*". Select your data file and it will be read into ***meteonorm***.

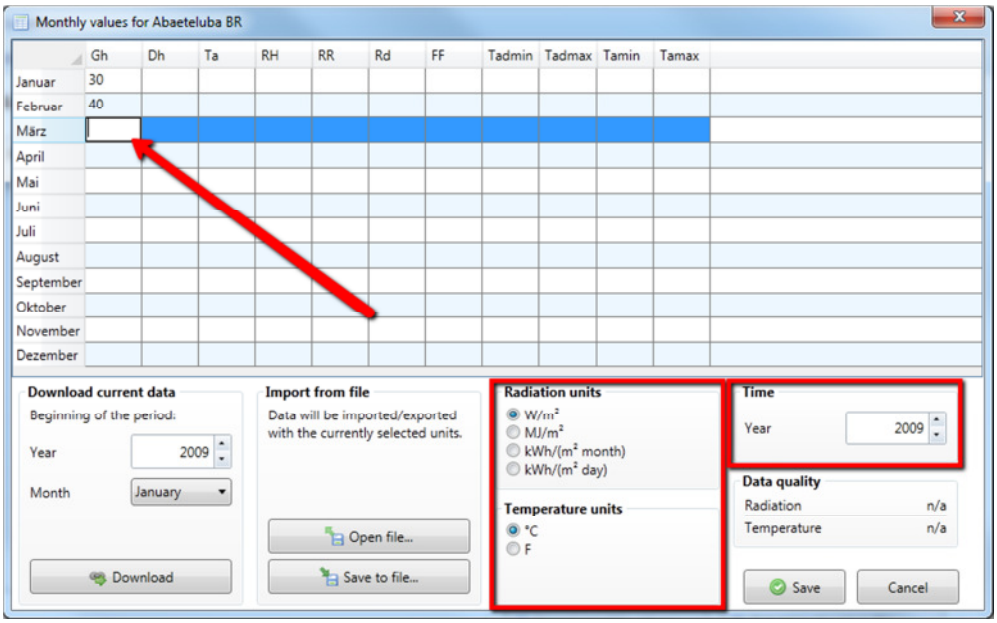




There is an example file located in *C:\ProgramFiles\METEOTEST\meteonorm7\Resources\Examples\Sample_monthly_values_for_Bern-Liebefeld-2011.csv*

2.4.1.1 Manual import

Another method to import your monthly values is to fill out the table from the Monthly values dialog by hand. Be aware to select the correct units of your radiation and temperature data. In the time field select the start year of your data. You can save your data by clicking the button "*Save to file...*". The file name will consist of the location name and the year entered in the time field.



2.4.2 Hourly values

With version 7.0 hourly values can be imported for every location. The software will change the type of site automatically to User (hour). First the import file has to be chosen in the register *Modifications* with the button *Select hourly files for import*.

Hourly data must be defined according to a predefined format. There are three different types of files which can be read:

- Italian weather station format
- Free format with tabulators as column separator and given header structure
- Energy Plus Weather format (EPW)

Italian weather station format

The Italian weather station format includes 11 header lines and the following parameters:
Year, month, day, day of year, hour, global radiation, temperature, relative humidity, precipitation, pressure, wind direction, wind speed and longwave incoming radiation. All radiation parameters must be in W/m^2, temperatures in °C, pressure in hPa and wind speed in m/s.

Free format

The parameters of the free format are specified in Table 2.4.2. Missing values are permitted and are to be coded as **-999**. Data series covering less than a full year are also permitted. A two line header is mandatory.

Tab. 2.4.2: Parameters for data import. The timestamp (m, dy or dm, h) is mandatory, all other parameters are optional. The parameters must be separated with tabulators. The abbreviations must be in the second line.

Abbreviation	Parameter	Unit
m	Month	
dy or dm	Day of year or day of month	
h	Hour	
gh	Global radiation	[W/m²]
ta	Temperature	[°C]
dh	Diffuse radiation	[W/m²]
bn	Beam radiation	[W/m²]
td	Dew point temperature	[°C]
rr	Precipitation	[mm]
ff	Wind speed	[m/s]

In the first header line the text "mn7 import file" must be written (with no additional tabulators). In the second line the different parameter abbreviations have to be listed. The order of the parameters can be chosen freely (make sure that header lines and values columns match).

The time definition used in the measurements have to be used in the definition of the site. The time is defined with the two parameters time zone and time reference (see chapter 6.1 in the Theory Manual).

If the definitions do not match, ***meteonorm*** tries to correct time definition in order to let the data be imported. If too many hours with global radiation at negative sun elevations or no global radiation with positive sun elevations occur, the import is stopped.

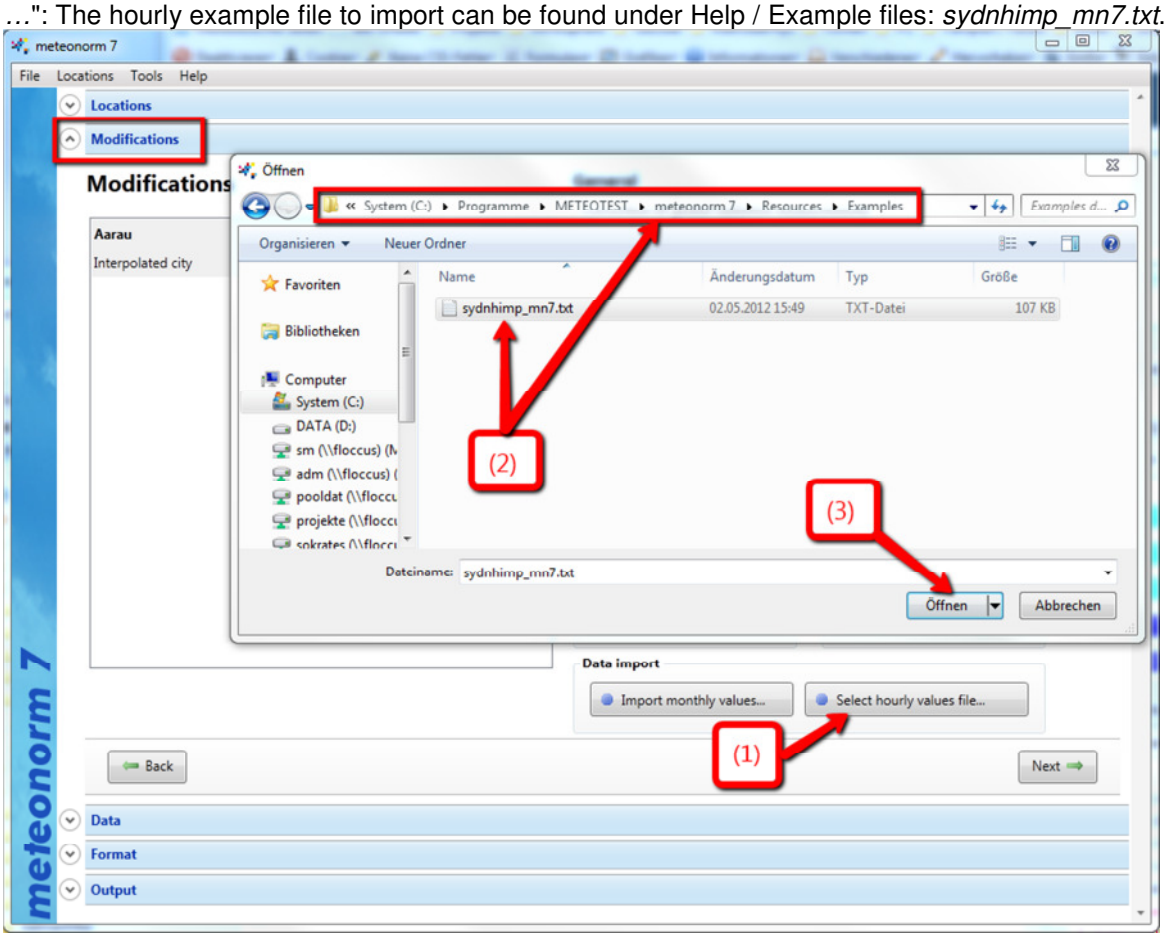
The easiest way to examine the time definition of the measured values is to save standard output values for the same site (change the type to "User defined site") for clear sky radiation with different time zones and time references and compare them to the measured time series e.g. in Excel.

2.4.3 Examples

Example: hourly values import

For a project in Sidney, Australia, hourly values for a complete year are to be imported. The measured data are from the Sydney weather station and were stored with normal time reference (Chap. 6.1), i.e. the IZRM = -30, and the time refers to the end of the measurement interval. Using the measured global radiation data in [W/m²], the radiation on a vertical, north facing (!) surface is to be calculated.

1. Selection of site: The first step is to select the site within Sydney (*Interpolated city*).
2. Specification of surface: azimuth: -180°, inclination: 90°.
3. Select the hourly import file in the register "Modifications" with the button "*Select hourly values file …*": The hourly example file to import can be found under Help / Example files: *sydnhimp_mn7.txt*.



4. Selection of output format: All output formats can be chosen. In this example the standard format is ok.
5. Click on Next or the Output register to run the calculation.
6. Save the results as PDF ("show preview for this location") or ASCII files (monthly, daily or hourly data).

3 Data Basis

In this chapter the data basis of ***meteonorm*** is presented, the sites to which the models were adapted and validated are listed, and the climatic classification system used for the generation of hourly values is defined.

3.1 Climatological Databases

3.1.1 Ground stations

In ***meteonorm***, several databases have been thoroughly checked to ensure reliability and were coupled to form a single comprehensive database permitting worldwide simulation of solar energy systems, buildings and environmental simulations. The database contains all necessary parameters for further processing (global radiation, temperature, wind, humidity and precipitation).

The Swiss database already used in the 1995 version 2 has been retained partly. This was compiled by the MeteoSwiss and contains 10-year mean data for Gh, Ta, FF, DD and Sd for 64 weather stations for the period 1983–1992. These values can be accessed for these sites for radiation parameters.

For worldwide applications, several different international databases are included. Global radiation data was taken from the GEBA Global Energy Balance Archive (WMO World Climate Program - Water) (Gilgen et al., 1998). The data was quality controlled using six separate procedures (checking of physical probability, time series analysis and comparison of cloud data). Temperature, humidity, wind data, sunshine duration and days with rain were taken from WMO Climatological Normals 1961–1990 (WMO, 1998). To replace missing data and ensure a homogeneous distribution of weather stations, other databases such as the data summary of international weather stations compiled by the National Climatic Data Center, USA (NCDC, 1995/2002) were added. For some stations in the USA, monthly mean values 1961–1990 of global radiation of the National Renewable Energy Laboratory (NREL) database "The Solar Radiation Data Manual For Buildings" were used.

For version 7.0 six data sources were updated:

- Swiss database (based on Swissmetnet of MeteoSwiss): The main period for radiation was extended to 1986–2005 for radiation and to 2000–2009 for temperature, wind and precipitation.
- Globalsod data (NCDC, 2002): The parameters temperature, wind speed (10 m above ground) and precipitation were processed to 2000–2009 means.
- GEBA: The main period was extended to 1986–2005.
- Turkish State Meteorological Service: 9 stations with global radiation from 2004–2010 were added.
- NREL: Monthly means of selected TMY3 sites (those within the lowest uncertainty class) were added.

The monthly average radiation values were calculated for periods of at least 10 years. Although the 10-year periods differ between the stations, a uniform period was used for each continent (Tab. 3.1.1). For some stations the data was extended with data from neighboring stations using a differential procedure. The database contains **a total of 8'275 weather stations**. Table 3.1.1 gives an overview of the global distribution and the type of the weather stations.

For most primary stations outside the USA, average values of temperature, humidity, wind and rainfall are available for the measurement period 1961–1990. In the USA, average values of these parameters are available for most weather stations for the period 1961–1990. All sites of type station (weather stations without global radiation measurements) now have average values for the period 2000–2009 (in version 5.x: 1961–1990, 6.x: 1996–2005).

Tab. 3.1.1: Distribution and number of available stations.

Available parameters	Global radiation and temperature	Temperature, additional parameters	Only temperature or radiation	Total
Europe	385	1'413	25	1'823
North America	281	2'466	39	2'786
South/Central America	95	594	66	755
Asia (with Russia)	265	1'246	39	1'550
Australia / Pacific	68	679	21	768
Africa	123	434	36	593
World	1'217	6'832	226	8'275

In addition to the monthly data, 1'020 DRY within the USA (tmy3 datasets based on 1991–2005 of NREL), the 15 German "Testreferenzjahre" (of DWD) and 45 additional sites of sia ("Merkblatt 2028", www.energycodes.ch) are included in ***meteonorm***. The sia datasets correspond to the period 1984-2003 and are based on EN ISO 15927-4. They can only be accessed with a special license (Add on: "sia Merkblatt 2028", see www.meteonorm.com/order/). 25 TMY3 datasets are included in the software. The rest can be downloaded from www.meteonorm.com/download/tmy3/.

3.1.2 Satellite data

In version 7.0 satellite data is used for radiation interpolation in remote areas (Fig. 3.1.1). Where no radiation measurement is available nearer than 300 km from the selected location, satellite information is used. If the nearest site is more than 30 km (Europe: 10 km) away, a mixture of ground and satellite information is used.

The method used for processing the satellite images is an approximation of methods like Heliosat II (Lefèvre et al., 2002): The 3 hourly pictures of the visible channel of the 5 geostationary satellites have been used (period 2003–2005). The satellite pictures are processed to daily means of global radiation and summed up to monthly values. These monthly values are interpolated with mean ground measurements (mainly GEBA data). The difference between the ground measurements and satellite information is interpolated spatially with the inverse distance method (see Chapter 6.2.1). This provides a result which includes the values at the ground stations and the variation of the satellite pictures.

For Europe a high resolution (2–3 km) satellite map has been compiled by MeteoSwiss based on images from 2004–2010 of the visible and the infrared channel of Meteosat Second Generation satellite. This data is included in ***meteonorm*** version 7.0

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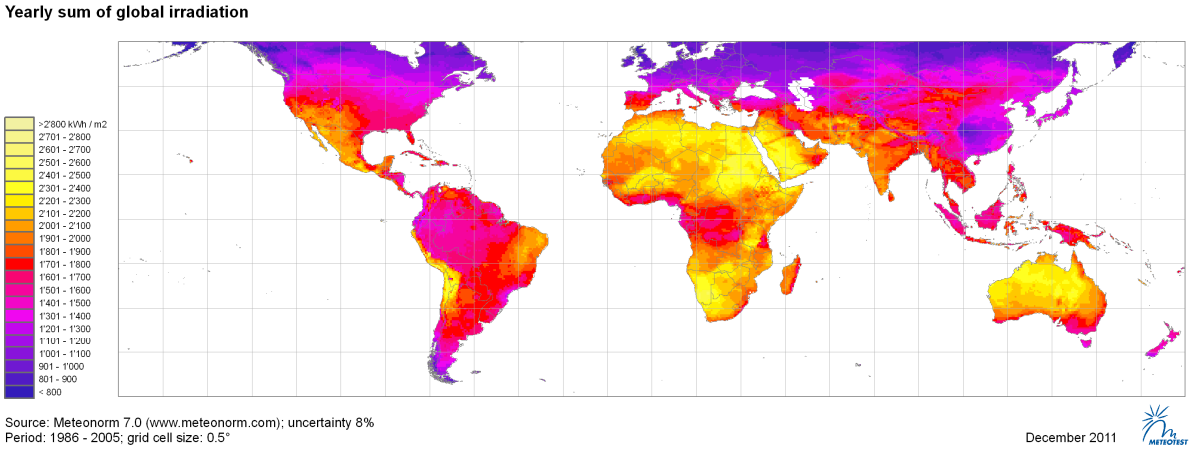

Fig. 3.1.1: Map of yearly sum of global irradiation in kWh/m² based on satellite and ground information. Means adapted mainly to the period 1986–2005.

3.2 Climate change data

From the IPCC report 2007 (Meehl et al, 2007) the average of all 18 models has been included in ***meteonorm***. Three different scenarios B1 (low), A1B (mid) and A2 (high) are available. The anomalies of temperature, precipitation, global radiation of the periods 2011–2030, 2046–2065, 2080–2099 were used for the calculation of future time periods.

The forecast changes of global radiation until 2100 with all scenarios are relatively small compared to temperature changes. They are in the range of one tenth of a percent up to some percent. The differences between the three scenarios are also relatively small (Table 3.2.1 and Figure 3.2.1). In average, the global radiation will slightly decrease. However, in the Mediterranean region the trend is positive (+ 2–4 % until 2100). The changes of the last 25 years go in the same direction but are already bigger than the forecasted anomalies for the period until 2030. However it has to be noted that the variations in the past 50 years (global dimming and brightening) have been underestimated by the climate models in the past.

Tab. 3.2.1: Change of mean global radiation values in scenario A2. Yearly means 1981–2000 according to ***meteonorm*** 6.1.

Site	longitude [°]	latitude [°]	Yearly mean *meteonorm* 6.1 [kWh/m²]	Anomalies 2011-2030 [kWh/m²]	Anomalies 2046-2056 [kWh/m²]	Anomalies 2080-2099 [kWh/m²]
Germany	10	50	1087	7 (0.6%)	14 (1.3%)	38 (3.5%)
South Spain	-5	37	1796	18 (1.0%)	28 (1.6%)	51 (2.8%)
Turkey	30	37	1952	15 (0.8%)	34 (1.7%)	69 (3.5%)
Sahara	0	30	2163	-9 (-0.4%)	-11 (-0.5%)	-14 (-0.6%)
World	-	-	1500	-10 (-0.7%)	-21 (-1.4%)	-29 (-1.9%)

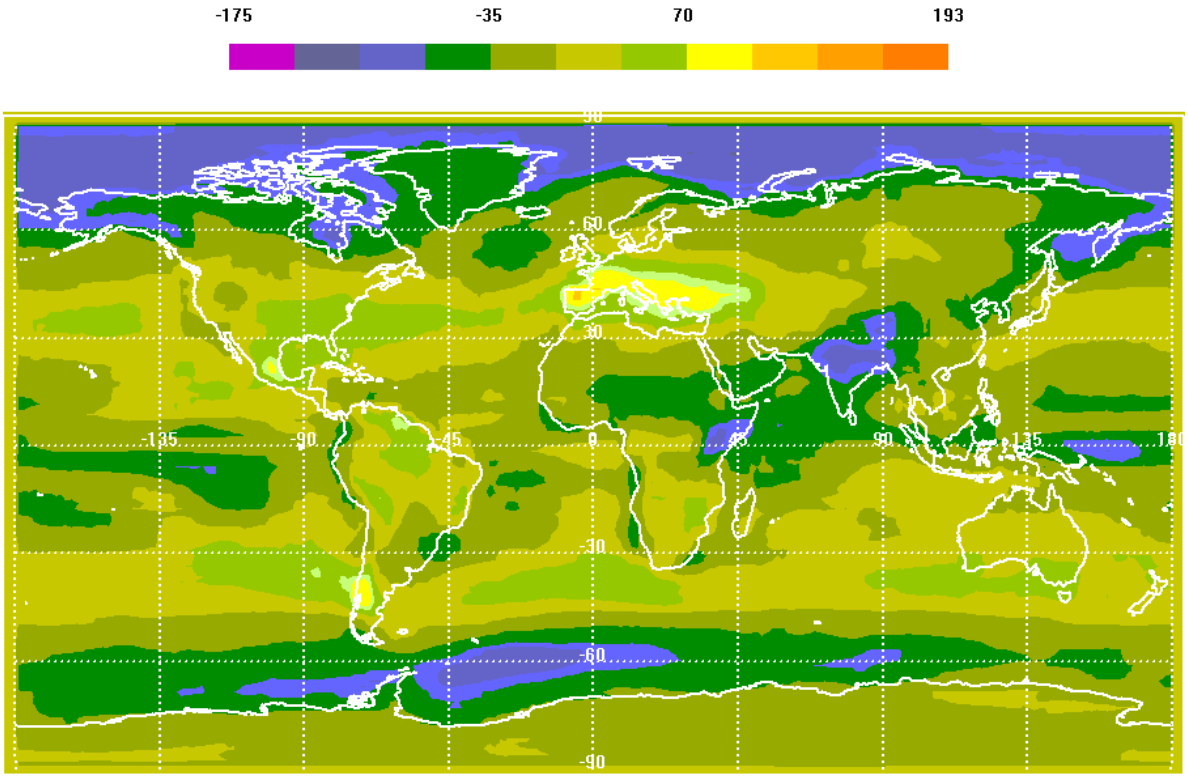

Fig. 3.2.1: Anomalies of global radiation in kWh/m² compared to 1961–1990 for the period 2080–2099 with IPCC scenario A2.

It is important to be aware that predictions from climate models are always subject to uncertainty because of limitations on our knowledge on the climate system and the development of emissions and on the computing resources available.

3.3 Climatic zones

In table 3.3.1 the climatic zones defined by Troll and Paffen (1980) are listed.

Tab. 3.3.1: The climatic zones defined by Troll and Paffen (1980).

I	**Polar and subpolar zones**	
	I, 1	High polar ice climates: polar ice deserts
	I, 2	Polar climates with low summer temperatures (< 6°C)
	I, 3	Subarctic tundra climates with cool summers
	I, 4	Subpolar maritime climates
II	**Cold temperate boreal zone**	
	II, 1	Maritime boreal climates
	II, 2	Continental boreal climates
	II, 3	High continental boreal climates with severe winters (< -25°C)
III	**Cool temperate zones**	
	Wooded climates:	
	III, 1	Elevated maritime climates with very mild winters
	III, 2	Maritime climates with mild winters
	III, 3	Submaritime climates
	III, 4	Subcontinental climates
	III, 5	Continental climates
	III, 6	Elevated continental climates
	III, 7	Warm summer, and humid summer and winter climates
	III, 8	Warm and humid summer climates
	Steppe climates:	
	III, 9	Humid steppe climates with cold or mild winters
	III, 0	Steppe climates with cold or mild winters and dry summers
	III, 1	Steppe climates with cold and dry winters and humid summers
	III, 2	Desert or semi-arid climates with cold or mild winters
IV	**Warm temperate zones, Subtropical climates**	
	IV, 1	Mediterranean climates with humid winters and dry summers
	IV, 2	Humid winter and very dry summer climates
	IV, 3	Short humid winter and dry winter climates
	IV, 4	Long humid summer and dry winter climates
	IV, 5	Desert and semi-arid climates without severe winters but with frost
	IV, 6	Perpetually humid grassland climates in southern hemisphere
	IV, 7	Perpetually humid hot summer climates
V	**Tropical zones**	
	IV, 1	Tropical rain climates
	IV, 2	Tropical humid summer climates
	IV, 3	Tropical humid winter climates
	IV, 4	Tropical dry climates
	IV, 5	Tropical desert or semi-arid climates

3.4 Additional data

For the Alpine countries wind and snow load zones have been added. Countries and the availability of load zones are listed in Table 3.4.1.

Tab. 3.4.1: Wind and snow load zones available in *meteonorm*.

Country	Wind load	Snow load
Switzerland	☑	☑
Germany	☑	☑
Austria	☒	☑
France	☒	☑

The load zones are shown in the monthly output of the two output formats Meteo and sia 380/1.

4 Abbreviations and Symbols

Tab. 4.1: Alphabetic index of abbreviations and symbols

Group	Abbreviation/Symbol	Description
General	Anetz	Automatic Network of the SMA
	SFOE	Swiss Federal Office of Energy
	DRY	Design Reference Year
	DWD	Deutscher Wetterdienst
	EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt
	gen	Generated
	mbe	mean biased error
	MN	meteonorm
	NABEL	Nationales Beobachtungsnetz für Luftfremdstoffe
	PV	Photovoltaics
	rmse	root mean square error
	WMO	World Meteorological Organisation
	SMI	Swiss Meteorological Institute, MeteoSwiss
Parameter	Bh	Direct radiation on horizontal surface
	Bk	Direct radiation on inclined surface
	Bn	Direct normal radiation (beam)
	DD	Wind direction
	Dh	Diffuse radiation (horizontal)
	Dh hor	Diffuse radiation (horizontal) with raised horizon
	Dh min	Diffuse radiation on clear days
	Dk	Diffuse radiation on inclined surface
	εh	Emissivity horizontal
	εv	Emissivity vertical
	FF	Wind speed (10 m above ground)
	FFE	Wind speed in E direction
	FFN	Wind speed in N direction
	FFaE, N, W, S	Wind fraction E, N, W, S (in %)
	<G>	Average radiation intensity
	Gh	Global radiation (horizontal)
	Gh hor	global radiation (horizontal) with raised horizon
	Gh max (Gc)	Maximum global radiation (on clear days) (horizontal)
	Gk	Global radiation on inclined surface
	GvE, N, W, S	Global radiation on vertical surface in E, N, W, and S directions
	H	Radiation time integral (radiation energy)
	HDD12/20	Heating degree days (with critical temperatures 12°C outside, 20°C inside)
	Lin	Longwave horizontal radiation impinging (longwave incoming)
	Lup	Longwave horizontal radiation emitted (longwave outgoing)
	Lv	Longwave radiation on vertical surface
	LG	Global illuminance
	LD	Diffuse illuminance
	mx	Mixing ratio
	N	Total cloud cover
	p	Atmospheric pressure
	PAR	Photosynthetically active radiation

Group	Abbreviation/Symbol	Description
	ρ	Albedo, reflection coefficient
	R	Radiation balance
	Rb	Ratio of direct radiation integral on inclined and horizontal surfaces
	RD	Days with precipitation > 0.1 mm
	R-Faktor	Ratio of global radiation integral on inclined and horizontal surfaces
	RH	Relative humidity
	RR	Precipitation
	Ta	Air temperature
	Td	Dew point temperature
	Tp	Wet-bulb temperature (psychrometer temperature)
	Ts	Surface temperature
	w	Water content of Atmosphere (precipitable water)
Earth	φ	Latitude
	φ'	Latitude of equivalent horizontal area
	λ	Longitude
Surface	β	Surface inclination
	γ	Surface azimuth (orientation of surface)
	Θ	Incident angle of radiation on inclined surface
	rD	Isotropic diffuse view factor
	rR	Isotropic reflex view factor
Sun	ma	Optical air mass
	δ	Declination
	γs	Solar azimuth
	hs	Solar altitude
	I0	Solar constant
	G0	Radiation at the upper edge of the atmosphere (Solar constant adjusted to distance earth-sun)
	Gex	Extraterrestrial solar radiation (horizontal)
	KT	Clearness index (month)
	Kt	Clearness index (day)
	kt	Clearness index (hour)
	So	Astronomical day (sunshine duration)
	Sd	Effective sunshine duration
	ωs	Hourly (solar) angle
	ωss	Hourly angles at sunrise and sunset
Time	dm	Day of month (1..28/29/30/31)
	dy	Day of year (1..365/366)
	ET	Time equation
	GMT	Greenwich mean time (=UTC)
	h	Hour of day
	hy	Hour of year
	IZRM	Internal reference time in min
	m	Month
	CET (MEZ)	Central European Time
	ST	True solar time
	t	Local time (time of day)
	ts	Time difference between local time and zonal time
	tz	Time difference between zonal time and universal time
	UTC	Universal time coordinated

5 Parameters and Units

5.1 Definition of Parameters

The following tables show the definitions and abbreviations of the parameters. Table 5.1 shows all the different meteorological parameters while table 5.2 shows the different radiation parameters.

Tab. 5.1: Definition of meteorological parameters.

Parameter	Description	Basic unit	Further units
DD	Wind direction	[°]	-
FF	Wind speed (FFE, FFN longitudinal and latitudinal part of the wind speed)	[m/s]	[1/10 m/s], [kt], [km/h]
FX	Gust peak speed (format "sia 2028" only)	[m/s]	[1 m/s]
H	Time integrated radiation (Index refers to radiation type)	[kWh/m²]	[MJ/m²]
G	Average hourly radiation intensity: (H/Δt) (Index refers to radiation type)	[W/m²]	[btu/ft² h], [kJ/m² h]
<G>	Average radiation intensity: (H/Δt) (Index refers to radiation type). For daily, monthly and yearly averages	[W/m²]	[btu/ft² h], [kJ/m² h]
hs	Solar altitude, i.e. the angle between the line joining the center of the sun with the site and the horizontal plane at the site.	[rad]	[°]
KTm, Ktd kt	Clearness index: Ratio of global radiation on earth's surface and extraterrestrial radiation (Gh / G0). KT refers to monthly values, Kt to daily values and kt to hourly values.	[ ]	-
mx	Mass mixing ratio: quantity of water vapor per kg of dry air	[g/kg]	-
N	Cloud cover	[octal units]	-
LG	Global illumance	[lux]	-
LB	Direct illuminance	[lux]	-
LD	Diffuse illuminance	[lux]	-
p	Atmospheric pressure	[hPa]	[1/100 inch Hg]
RD	Days with Precipitation > 0.1 mm	[d]	-
RR	Precipitation	[mm]	-
RH	Relative humidity	[%]	-
w	Precipitable water	[g]	-
dr	Driving rain		
Enthalpy	Enthalpy	[kJ/kg]	
snow	Snow depth	[cm]	
ρ (rho)	Albedo	[ ]	
Sd	Effective sunshine duration	[h]	-
Ta	Air temperature (ambient temperature, 2 m above ground)	[°C]	[1/10 °C], [F]
Ta min/max	Lowest/highest hourly temperature per month	[°C]	[1/10 °C], [F]
Ta dmin/dmax	Average minimum/max. daily temperature	[°C]	[1/10 °C], [F]
Td	Dew point temperature	[°C]	[1/10 °C], [F]
Tp	Wet-bulb temperature (psychrometer temperature)	[°C]	[1/10 °C], [F]
Ts	Surface temperature (5 cm above ground)	[°C]	[1/10 °C], [F]
tl	Linke turbidity factor	[ ]	

Tab. 5.2: Definition of the radiation parameters.

Parameter	Description
Bc	Direct normal radiation, clear sky
Bh	Direct radiation horizontal, i.e. shortwave radiation ($\lambda < 3$ μm) arising from a narrow solid angle (6° aperture) centered around the sun's disk impinging on a horizontal surface
Bk	Direct radiation inclined, i.e. shortwave radiation ($\lambda < 3$ μm) arising from a narrow solid angle centered around the sun's disk (6° aperture) and impinging on an inclined surface
Bn	Beam, i.e. direct normal radiation (DNI). Shortwave radiation ($\lambda < 3$ μm) arising from a narrow solid angle (5° aperture) centered around the sun's disk and impinging on a surface normal to the direction of the radiation.
Dc	Diffuse radiation horizontal, clear sky
Dh	Diffuse radiation horizontal, i.e. shortwave isotropic radiation ($\lambda < 3$ μm) arising from the upper hemisphere reduced by the direct solar radiation from the sun's disk and its surroundings (6° aperture)
Dh hor	Diffuse radiation horizontal with raised horizon, i.e. shortwave isotropic radiation ($\lambda < 3$ μm) arising from the upper hemisphere reduced by the direct solar radiation from the sun's disk and its surroundings (6° aperture) taking raised horizon into account
Dh min	Diffuse radiation, horizontal, minimum: Minimum diffuse radiation on horizontal surface on clear, cloudless days (clear sky conditions)
Dk	Diffuse radiation inclined, i.e. shortwave isotropic radiation ($\lambda < 3$ μm) arising from the upper hemisphere reduced by the direct solar radiation from the sun's disk and its surroundings (6° aperture) on inclined surface
Gh	Global radiation, horizontal, i.e. shortwave radiation ($\lambda < 3$ μm), received by a horizontal surface from the solid angle 2π
Gh hor	Global radiation horizontal with raised horizon, i.e. shortwave radiation ($\lambda < 3$ μm) received by a horizontal surface from the solid angle 2π, taking raised horizon into account
Gh max (Gc)	Global radiation, horizontal, maximum, i.e. maximum global radiation on horizontal surface on clear, cloudless days (clear sky conditions)
Gk	Global radiation, inclined, i.e. shortwave radiation ($\lambda < 3$ μm), received by an inclined surface from the solid angle 2π
GN	Global radiation, tracked (2 axis tracking; plane normal to the direction of the sun)
Gex	Extraterrestrial radiation, horizontal, i.e. shortwave radiation ($\lambda < 3$ μm) arising from the sky (upper hemisphere) on a horizontal surface at the upper edge of the atmosphere
Lin	Longwave (thermal, infrared) radiation on horizontal surface arising from the sky (upper hemisphere) (longwave incoming), wavelength > 3 μm
Lup	Longwave (thermal, infrared) radiation on horizontal surface emitted from the earth's surface (longwave outgoing) wavelength > 3 μm
Lv	Longwave (thermal, infrared) radiation on vertical surface, wavelength > 3 μm
PAR	Photosynthetically active radiation (always in W/m²)
R	Radiation balance , i.e. balance of total incident and emitted radiation (short and longwave)
UVA (UVAc)	UVA radiation (clear sky radiation)
UVB (UVBc)	UVB radiation (clear sky radiation)
UVE (UVEc)	Erythemal UV radiation (clear sky radiation)
UV Index	Mean daily maximum of UV index at clear sky conditions (UV index = 40 x Erythemal UV)

Note: As most computer programs do not provide for subscripts, there are two modes of representation for each variable. In the ***meteonorm*** program and most of the figures, the subscripts are represented by a suffix preceded by an underscore.

Example of variable representation:

G_Gh : Designates average hourly radiation intensity for global horizontal radiation.
H_Gh : Designates time integral of horizontal global radiation which corresponds to the energy absorbed.

5.2 Conversion Factors

The conversion factors used for converting units are provided in Table 5.3.

Tab. 5.3: Conversion factors for conversion of units (Krist, 1976).

	Parameter	Basic unit (1)	Required unit (2)	Formula
Radiation	H	[kWh/m²]	[MJ/m²]	(2) = 3.6*(1)
	<G>	[W/m²]	[kJ/m² h]	(2) = 3.6*(1)
			[btu/ft² h]	(2) = 0.317*(1)
			[MJ/m² h]	(2) = 0.0036*(1)
			[MJ/m² mon]	Month with 28 days: (2) = 2.42*(1) 30 days: (2) = 2.59*(1) 31 days: (2) = 2.68*(1) Year: (2) = 31.54*(1)
			[kWh/m² h]	(2) = 0.001*(1)
			[kWh/m² day]	(2) = 0.024*(1)
			[kWh/m² mon]	Month with 28 days: (2) = 0.67*(1) 30 days: (2) = 0.72*(1) 31 days: (2) = 0.74*(1) Year: (2) = 8.76*(1)
Temperature	Ta, Td, Tp	[°C]	[°F]	(2) = 1.8*(1)+32
Wind	FF	[m/s]	[kn]	(2) = 1.94*(1)
			[km/h]	(2) = 3.6*(1)
Pressure	p	[hPa] = [100 N/m²]	[1/100 inch Hg]	(2) = 2.95*(1)

[btu]: British thermal unit